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# THE BERMUDA ISLANDS AND THE BERMUDA BIOLOGICAL STATION FOR RESEARCH.*

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I FEEL a certain hesitancy in speaking on the subject I have selected to talk about—the Bermuda Islands—because of the number of prominent naturalists who have written so excellently about them. It should be stated at the outset that I do not aim to add to the stock of our knowledge about the Bermudas. So much has been written about their zoology in recent years—especially by the zoologists of the *Challenger* Expedition, then by Professor Heilprin of this city, on the invertebrates and the coral reefs, by Mr. Agassiz, incidental to his studies of the great question of the origin and growth of coral reefs, and most recently by that veteran in systematic zoology, Professor Verrill, of Yale University—that it is hardly to be expected that anything fundamentally new will be soon added. It is my purpose, rather, to give something of a picture of the present conditions in Bermuda, based partly on my own experiences, and particularly to direct your attention to the accessibility of the islands and their availability as a place for carrying on intensive rather than extensive researches. With the facilities for work which will soon be provided by the colonial government, it should be an attractive place not only for temporary exploration and summer study, but also for protracted investigations on important biological problems.

My own interest in Bermuda as a place for zoological study was first awakened by suggestions of President Eliot, who a few years ago

* A vice-presidential address prepared for Section F (Zoology) of the American Association for the Advancement of Science, at its Philadelphia meeting.

passed the winter in Bermuda, and upon his return inquired of me if I did not think it would be a good place for a marine laboratory. The more I inquired into the condition of living in the islands, and the marine organisms in the sea about the islands, the more I became convinced of the practicability of the place for a biological laboratory.

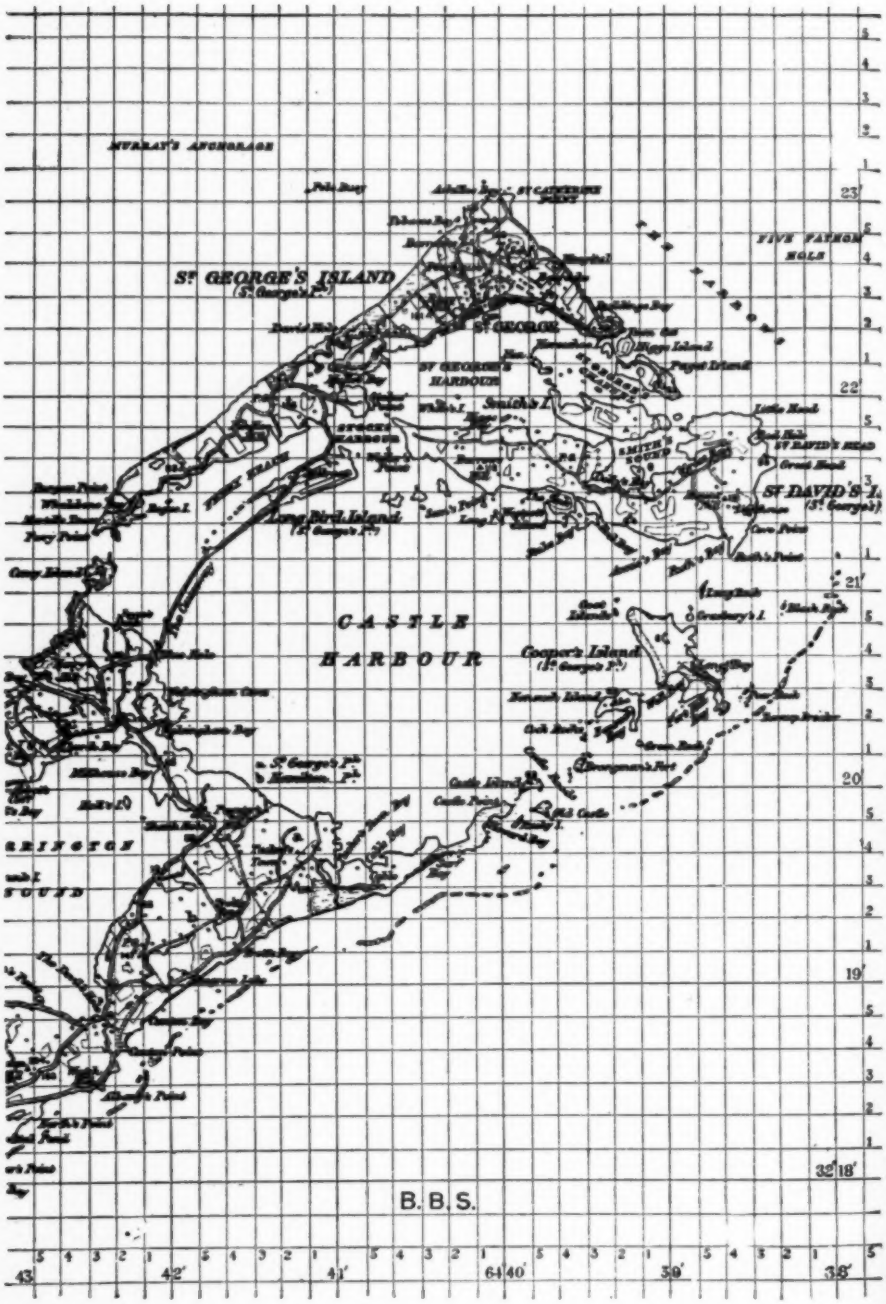
At the risk of saying much that is already familiar to many of you, I will give an account of some of the things which seem to me of interest in this connection.

From fifty to sixty hours' steaming brings one from New York to Bermuda. It is worthy of note that the distance of the islands from New York or Boston is only about two thirds that of the Dry Tortugas or the Bahamas. The climate and the conditions of life in the Bermudas are safe and agreeable at all seasons of the year. Though the humidity is considerable, the temperature in summer rises to only 85° or 86° Fahrenheit; in winter it seldom gets below about 50°, and never to the freezing point. To the zoologist familiar with the animals of our north Atlantic coast and the water they live in, the waters that wash the shores of these islands and the brilliantly colored animals that inhabit them are a source of surprise and delight.

Leaving New York a little before noon on Saturday, the islands are usually sighted about mid-day on Monday, and landing is made in Hamilton a few hours later. If one has pictured to himself low-lying coral islands fringed with palm trees, he will be disappointed, and will be surprised to find that the land rises in many places to a considerable height—even to two hundred and fifty feet or more—and on approaching nearer to see, instead of palms, the dark green of the cedars that cover many of the hills. In passing from the deep waters of the Atlantic to the shallower depths near land, the dark blue of the ocean is replaced by livelier tints, in which greens predominate, and when the conditions of sun and sky are favorable, the variety of colors exhibited is truly wonderful. Even the far-famed Bay of Naples does not afford a more brilliant display of colors than is sometimes seen in the waters around the Bermudas.

In contrast with these fascinating, kaleidoscopic effects of the sea, the land presents either the dull gray appearance so common on the granite shores of New England, or the dark green of the cedars, which also reproduce the effect of the New England evergreens. If one could ignore the colors of the sea, he might easily imagine, as he steams along the northern shores of the Bermudas, that he was skirting some part of the Maine coast. One thing, however, would impress him as strange—the brilliant white specks and patches which here and there dot the hillsides or are clustered into larger or smaller groups—the limestone dwellings of the Bermudians. These with their white roofs, brilliant in the sunlight, are in marked contrast to anything seen on

MAP 1. CHART OF THE BERMUDA ISLANDS, WITH SOUNDINGS IN FATHOMS, THE HUNDRED-FATHOM LINE (DOTTED), THE SHIP CHANNEL (DASHES), AND THE LATITUDE AND LONGITUDE TO MINUTES.




MAP 2. NORTHEASTERN THIRD OF THE BERMUDA ISLANDS, WITH LATITUDE AND LONGITUDE LINES TEN SECONDS APART.

the Maine coast. Government House, on Mount Langton—the residence of the governor of the islands—is a conspicuous building on the crest of the ridge which hides the city of Hamilton from the approaching voyager.

After a long and rather circuitous course through the only channel available for steamers, and under the guns of several forts, one at length enters Hamilton Harbor between two rocks that are not far enough apart to allow the passage of two ships abreast. The still unfinished cathedral, two modern hotels for the accommodation of winter tourists, and the parliament house are the most conspicuous buildings in Hamilton, being situated on the highest part of the slope occupied by the town (Fig. 1).

The substantial city dock, with its low, unattractive sheds roofed in by arched and corrugated metal, extends along the whole water front.

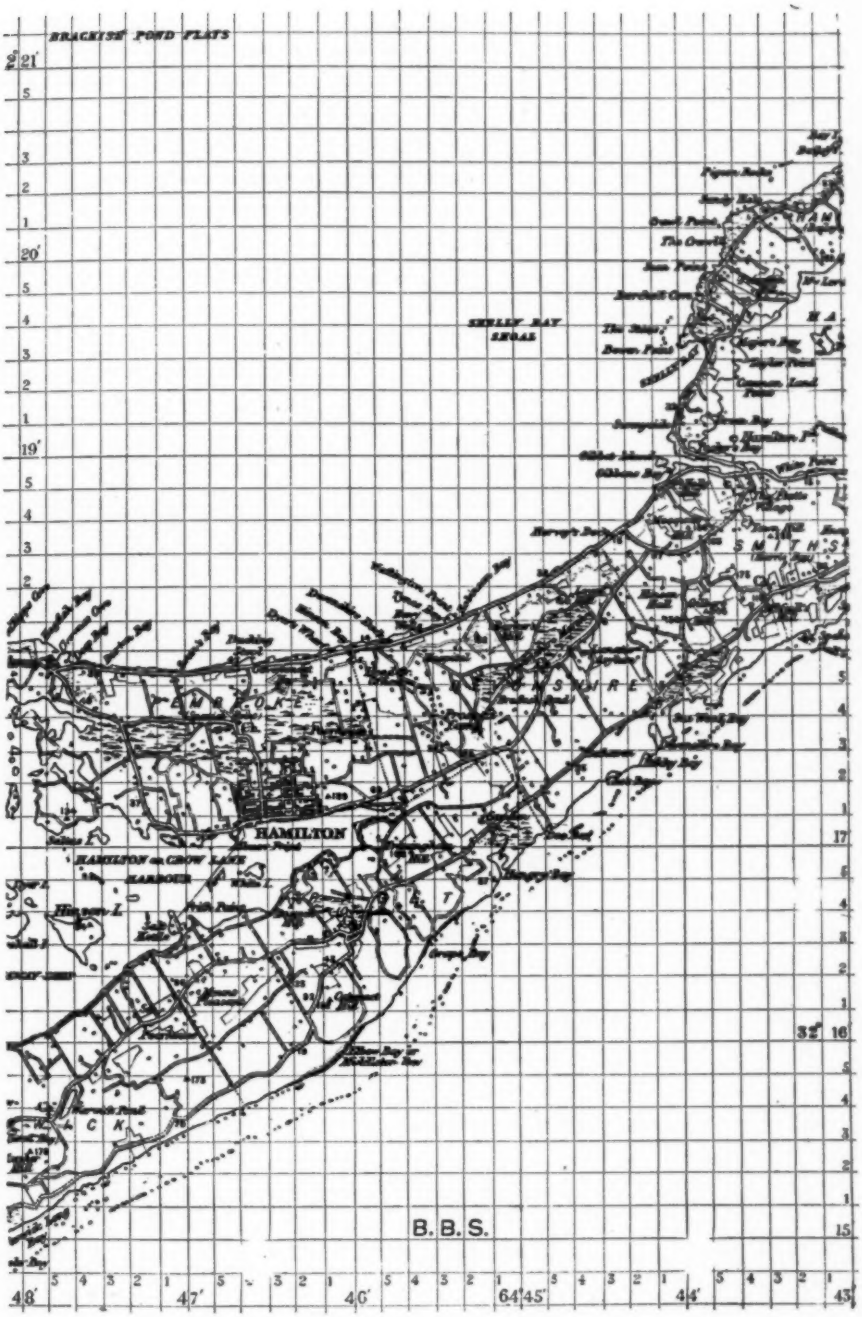
FIG. 1. VIEW OF HAMILTON FROM THE HARBOR. From a photograph by Phelps Gage.

Beyond the sheds runs Front Street (Fig. 2) parallel to the shore. Across the street from the sheds are the chief business houses of the town; some of them having a modern look, but the greater part of them with small windows and heavy solid wooden shutters that recall the northern country store of fifty or seventy-five years ago. Unlike the country store, however, the Bermuda store has a two-story portico extending out over the side-walk, so that the pedestrian is partly sheltered by it from the heat of the sun or the sudden down-pour of the unannounced shower that is so characteristic of the islands. The second story of this portico, like most of the dwellings (compare Fig. 3), is enclosed by shutters with immovable slats, which keep out heat and rain, but permit a free circulation of air within. The vehicles in the street range from the modern rubber-tired victoria to the low two-wheel cart drawn by horse, mule or ox.

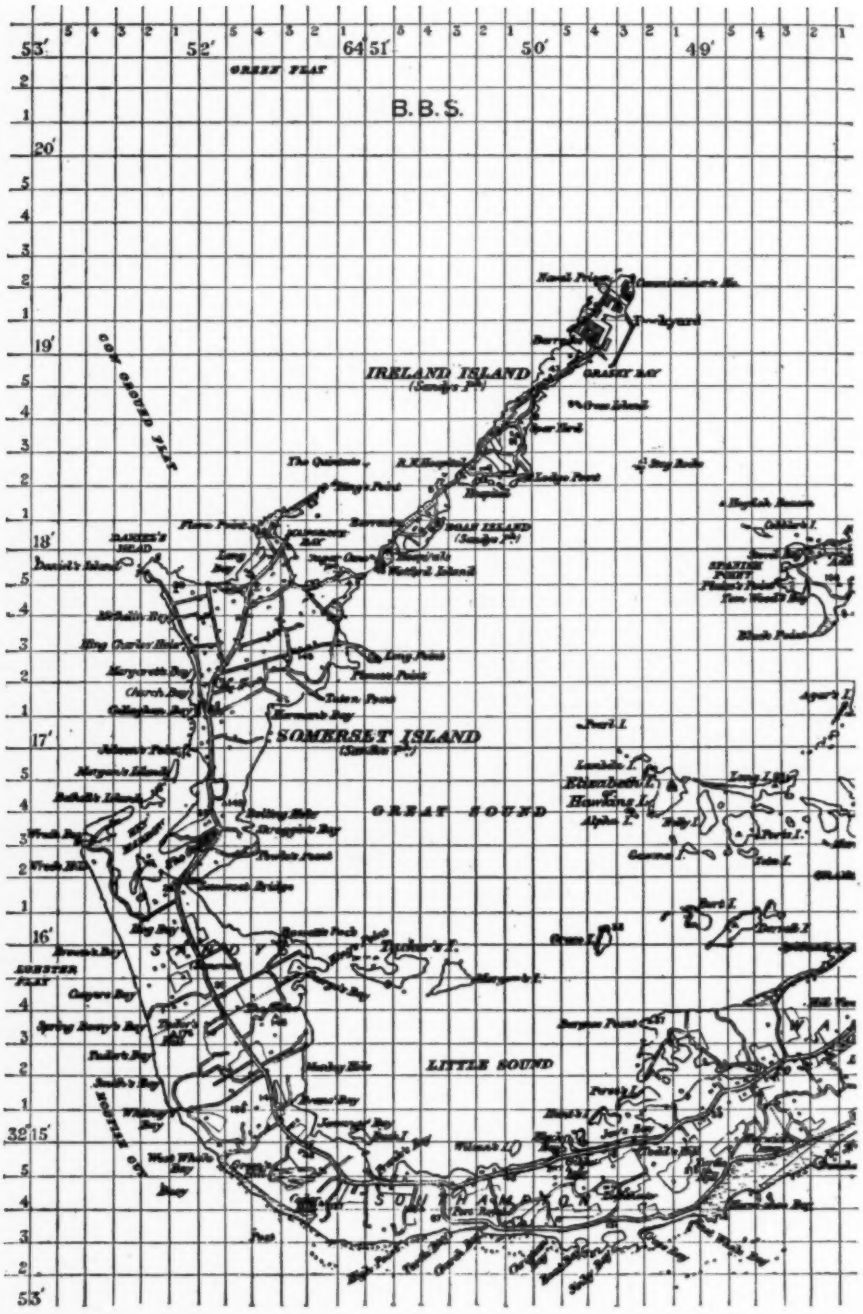
As a glance at the map will show (Map 1), the Bermudas consist of a chain of about half a dozen islands so grouped that the whole bears a fancied resemblance to a gauntlet. The broad wrist region at the northeast is made up of St. David's, Smith's and St. George's islands and a part of the main, or Bermuda, island, the rest of which stands for the hand, the thumb and the first joints of the fingers, the remaining joints of the fingers being represented by Somerset and Ireland islands. The whole length of the group from northeast to southwest is about fifteen miles, and the width is usually a mile or at most two miles; in many places it is much less. A fairly continuous ridge occupies the axis of the islands mentioned. Besides these larger islands, there are numerous smaller ones (Fig. 4), so that it may well be that there is, as claimed, an island for every day in the year. The larger islands are so indented by bays and sounds that it is evident they will

FIG. 2. FRONT ST., HAMILTON. U. S. CONSULATE IN THE DISTANCE. Photograph by L. J. Cole.

in time become divided up into smaller ones, and thus add to the existing number. The largest of the bodies of water on the north that seem to have eaten their way into the land masses is Castle Harbor (Map 2). This lagoon is from two to three miles in diameter, and communicates with the open sea on the southeast by several passages separating from each other as many small islands, and with a great northern lagoon by means of a long narrow arm of the sea called Ferry Reach. Connected with Ferry Reach at its northeasterly end is St. George's Harbor, which affords an excellent and well protected anchorage. Southwest from Castle Harbor, and separated from it by only a narrow ridge, is Harrington Sound, which looks like an inland lake (Fig. 5); it is a mile wide, two miles long, and in places sixty or seventy feet deep. This has but one communication with the sea above ground,




MAP 3. THE MIDDLE THIRD OF THE BERMUDA ISLANDS. THE POSITION OF THE LABORATORY IS INDICATED BY THE LINES '390' AT THE MARGINS OF THE MAP.




MAP 4. SOUTHWESTERN THIRD OF THE BERMUDA ISLANDS.

though there are several underground connections. This single surface-connection is by means of a passage only about thirty feet wide, through which the water rushes with great swiftness during every tide. It is surprising for how short a time at the turn of the tide, five or ten minutes only, the water is relatively quiet. This narrow passage leads directly to the Flatts Inlet, which in turn connects with the great north lagoon. The inlet, not being very broad, is therefore swept by a rather strong current. This region ('The Flatts,' Map 1) is of particular interest to us, for it is on this inlet that our laboratory is located.

All the waters held, as it were, in the hand of the fancied gauntlet —Great Sound, Little Sound (Map 4), Hamilton Harbor (Map 3),

FIG. 3. RESIDENCE SURROUNDED BY PALMETTO TREES. Photograph by Phelps Gage.

etc.—form another extensive landlocked sea, which formerly, in all probability, communicated less freely with the north lagoon than at present, for a submarine ridge runs out from Spanish Point—the tip of the thumb (Map 1)—to Ireland Island. At several points this ridge is awash at low tide.

Through the greater part of the main island there are three parallel roads (Map 3): one—known as the middle road—runs in a general way along the ridge; the others—known as north and south roads—run along the north and south shores. The north and middle roads meet at The Flatts, and nearly all the travel between the only two cities, Hamilton and St. George's, passes over the bridge which crosses the gorge between the inlet and Harrington Sound.

The houses of Bermuda are, almost without exception, made of the

limestone rock which everywhere abounds. This is cut into blocks a foot or more in length, eight or ten inches wide and of different thick-

FIG. 4. GREAT SOUND, LOOKING SOUTH FROM SPANISH POINT.*

nesses. Even the roof is made of thin overlapping slabs of the same rock supported by slats that rest on wooden rafters. The houses, roof

FIG. 5. HARRINGTON SOUND. Photograph by A. H. Verrill.

and wall, are whitewashed at frequent intervals, usually twice a year. The rain that falls on the roofs is carefully collected in covered cisterns, for it is the only source of fresh water in the islands, since

* I am greatly indebted to Professor A. E. Verrill for the use of about half of the figures, those which he has furnished having been taken from *The Transactions of the Connecticut Academy of Science* and from his 'The Bermuda Islands,' New Haven, 1902, and 'Zoology of the Bermudas,' New Haven, 1903.

there are no streams, and most of the rain pools last but a few hours even after the heaviest shower. In some localities barren tracts of land are denuded, the rock cut to a sloping surface and whitewashed to serve as a watershed for collecting rain water in larger quantity than the roofs supply.

In addition to the garrisons and the marines there are on the islands about 18,000 people, two thirds of whom are negroes, the rest whites, mostly of English extraction. There is a property qualification for voting; the proportion of whites to blacks on the voting list is two to one, the reverse of the ratio in population.

FIG. 6. ANCIENT STREET IN ST. GEORGE'S.
Photograph by A. H. Verrill.

The cities, as I have said, are but two: the quaint town of St. George's and the more modern town of Hamilton. St. George's is the more interesting because of its tortuous narrow streets, its high garden walls and its ancient architecture, which suggest a medieval European town (Fig. 6). It was the seat of government until about a hundred years ago (1815), and retained for a long time after that an importance due largely to its fine harbor.

The visible land of Bermuda gives a very incomplete idea of the shape of the submarine plateau from which it rises. If the sea were to recede so that its surface was about thirty feet below its present level, we should have a great oval lagoon some twenty-five miles long and from twelve to fifteen wide, the rim of which would be made up in part of the present land area, and for the rest of a more or less continuous reef of coral-covered rocks a mile or so wide (Map 1). The great central basin—the great north lagoon, as I have called it—would have no considerable depth—seldom more than fifteen or twenty feet of water, and nowhere more than thirty—and would be studded with innumerable coral rocks and islands. Some of the deeper parts have special names, as Murray Anchorage and Grassy Bay, while the shallower parts are known as flats—Brackish Pond Flats, Bailey's Bay Flats, etc. The passages through this rim would be only three: Hogfish Cut, Chub Cut and the Narrows or Ship Channel. The slope of the sea bottom outside the rim is rather abrupt on the southeast side of the oval, less so on the northwest side, and least of all at the ends, as the position of the hundred fathom line shows. Beyond the hundred fathom line the bottom slopes even more rapidly to a depth of

1,200, 1,500 or even in places to 2,000 fathoms. These depths are reached at from two to five miles beyond the hundred fathom line.

Rising from the floor of the sea some ten or twelve miles to the southwest of this oval plateau is another much smaller one, which would still be some 150 or 200 feet under the surface were the sea to recede, as we have imagined, thirty feet. This is known as the Challenger Bank.

Ten miles beyond this is another similar plateau of about the same size and height, called the Argus Bank. These two banks are in reality a part—two detached peaks, as it were—of the great submarine mountain of which the Bermuda Islands are the visible summit. For

FIG. 7. ROAD CUTTING NEAR HAMILTON.

while the floor of the ocean sinks within five miles to about 1,500 fathoms, these plateaus are separated from each other and from the Bermuda plateau by less than half that depth.

The present land area of all the Bermuda Islands is composed of calcareous rock which varies from a loose sand to a firm, hard, semi-crystalline limestone that resounds to the blow of the hammer. What underlies this, no one yet knows. The deepest excavations—those for the new Navy Yard docks at Ireland Island—have not disclosed any other kind of rock. The numerous deep cuts for roads (Fig. 7) and the quarries which are met with in all parts of the islands tell the same story. The rocks are composed of wind-blown calcareous sand. This sand, contrary to what was formerly supposed, is not composed of broken down corals. These are present only in small proportion, the

chief constituents being fragments of shells, serpula tubes and corallines. There are no such stratified subaqueous rocks as are found in this country, but everywhere the cut edges of the rocks show the peculiar sinuous lines that characterize the stratification of drifting sands. Most—if not all—of the harder rocks are doubtless the result of the action of water and air on these æolian masses. At almost every point where the action of the sea is traceable it has resulted either in cementing together the layers of these rocks till all evidence of stratification is

FIG. 8. WATER-WORN ROCKS, SOUTH SHORE.

lost, or else its mechanical effect has been more immediate than its chemical, and the rock has crumbled into its constituent grains and has become once more a sandy beach, in turn yielding up its substance to build the present sand dunes of the coast, which have the same æolian structure as their predecessors.

The mechanical action of the sea operating on the already hardened rocks has left them carved in the most fantastic shape (Figs. 8, 9), and with edges so sharp that it is almost impossible to walk upon them. In many places the rocks are honeycombed through the action of water, and subterranean passages connect inland waters with the sea. Caves, too, sometimes of considerable extent, are found at various places, especially

FIG. 9. CATHEDRAL ROCKS, LOOKING NORTH. Photograph by A. H. Verrill.

in the northern part of the islands, about Castle Harbor and Harrington Sound. The floors of these caves are in some places below sea level, and since there is a free communication with the sea, deep pools of sea water are not uncommon in them. The water is so clear and unruffled that the incautious visitor is liable to walk into the pools unawares, even after being especially cautioned against it. The stalactite and stalagmite formations point to the solvent action of water as the cause of the caves. It is highly probable that many of the depressed areas of the land known as 'sinks,' as well as the sounds and harbors, are the result of the falling in of the roofs of caves. The 'sinks' vary in area from a few square yards to many acres.

FIG. 10. ROYAL PALMS AT PEMBROKE HALL, NEAR HAMILTON.

These depressions contain the peculiar reddish brown earth that makes farming and gardening possible in the Bermudas. The richness of this soil and the favorable climate allow the farmer to keep the earth under constant cultivation and to procure several crops in the course of a year.

Although trees and shrubs in great variety are to be found in Bermuda, most of them are not peculiar to the islands, but probably owe their origin to introduction by natural agencies from the West Indies and the United States before historic times, while many are known to have been introduced by man, and not a few of these within comparatively recent times. The Bermuda cedar (*Juniperus bermudiana*) may be indigenous, though fifty years ago it was also found in the Blue Mountains of Jamaica. The palms—a dozen species of which are said to be growing in the islands—and the palmettos, are the most noticeable growths to attract the eye of the northener. The royal palm (Fig. 10) surpasses all others both in height and in beauty, but the cocoanut palm (Fig. 11) is a worthy second, and many specimens of it are striking features of the landscape. In Queen Street, Hamilton, one drives beneath the sprawling branches of what we call a 'rubber plant' when it grows in pots in our conservatories. Here its branches have a spread of a hundred feet or so. On entering the Public Garden at St. George's, where many interesting exotics are found, one is confronted by a stately screw pine of most symmetrical

form twenty or thirty feet high, and in the Agricultural Gardens near Hamilton, another *Pandanus* of less graceful form but greater breadth is seen. Our common deciduous trees, however,—the maples, beeches, birches and oaks—are entirely wanting. In a private garden that contained many interesting trees and shrubs from various parts of the world

FIG. 11. 'WISTOWE,' RESIDENCE OF THE WIDOW OF THE LATE U. S. CONSUL, THE HON. C. H. ALLEN.

I was shown, as one of the greatest of curiosities, a sickly specimen of one of our oaks. Even with the utmost care and attention these trees can not be made to flourish in Bermuda; but oleanders have been introduced and flourish almost beyond belief. They are often used as hedgerows and grow to a height of twenty or twenty-five feet. A great variety of tints from deep scarlet—almost crimson—to pure white are to be seen. From May to September they enliven the face

of the land with their brilliant colors, which occur in such masses that they are the admiration of all who see them. On the bleak north shores, the tamarisk has been planted as a break against wind and salt-water. Though not an especially graceful shrub, the soft green of its fine-cut foliage makes a pleasant impression on the eye, and it enjoys the great practical advantage of being about the only kind of verdure that can really thrive in the presence of the abundant salt-spray which the prevailing winds drive in upon the land.

The fiddle-wood tree (*Citharexylum quadrangulare*) is to-day the commonest of the deciduous trees in Bermuda, but the first tree of this species on the islands—the one from which all the others are reported to have come—was imported as recently as 1830, and is still standing. The Pride of India (*Melia azedarach*) is a rather scraggy, forlorn looking tree in mid-summer, and one wonders why it is so much cultivated; but in early spring, before the leaves are out, it puts forth a profusion of pink flowers that makes it a great favorite with the Bermudians. It seems as though Bermuda must be the home of the genius *Hibiscus,* so many species are met with. In mid-summer their blossoms exhibit some remarkably gorgeous colors. Still, the most superb of all the ornamental trees and shrubs to be seen here is the *Poinciana regia,* a native of Madagascar, a tree with spreading branches clothed in the most pleasing green and decked with beautiful clusters of brilliant red blossoms.

The land animals, with the exception of insects and mollusks, are remarkably few, and of these most are probably not natives of the islands any more than are the majority of the phænogamic plants.

Except for domesticated animals, mammals are numerous neither in species nor in individuals. The most interesting one is doubtless the wood rat (*Mus tectorum*), which lives in trees and is now nearly extinct. This was at one time a dreaded scourge to the early settlers. Nearly 300 years ago (1619), Governor Butler, writing of the timely arrival of a so-called runaway frigate that brought food and thus averted impending famine, said:

> But howsoever this runne away frigate brought with her a timely and acceptable sacrifice of her meale; yet the companions of her meale, numbers of ratts (which wer the first that the ilands ever sawe), being received with-all and on a soudaine multiplyinge themselves by an infinite increase (for ther is noe place in the world so proper for them), within the space of one only yeare they became so terrible to the poore inhabitants, as that (like one of Pharaoths plagues) the whole plantation was almost utterly subverted therby; and so farr gone it was at last, that it proved Captaine Tucker's masterpiece all his time (which was not long after) to devise trapps and stratagems to conquer and destroye them, though indeed all of them proved to noe purpose (as you shall see hereafter) untill afterwards, one moneth of cold and wett weather did the deed.

It is by no means certain, however, that these rats had not long existed on the islands, even though an earlier writer—Silvanus Jourdan, says (1610):

> The countrey (foreasmuch as I could finde myself, or heare by others) affords no venimous creature or so much as a Rat or a mouse, or any other thing unwholesome.

Whales, which were once of some commercial importance to the islands, are so rare that they are no longer hunted, and the 'whale houses,' of which there were recently half a dozen in existence, are but relics of an industry that has practically ceased.

The greater part of the 150 or more birds mentioned by Major Wedderburn (Jones: 'The Naturalist in Bermuda') as found in the Bermudas, are migrants. The most conspicuous and interesting

FIG. 12. TROPIC BIRDS. Photograph by A. H. Verrill.

of them is the tropic or boatswain bird (Fig. 12), which still continues to nest here, usually on the more remote and inaccessible islands.

The only representative of the Amphibia is the great Surinam toad (*Bufo agua*), which was introduced into Bermuda some twenty-five or thirty years ago by Captain Nathaniel Vesey to combat insect pests. I was fortunate enough during my first visit to the islands to find several of these toads spawning on the morning of April 22. There

had been a heavy shower during the preceding night, which had resulted in temporary pools of fresh water in a few places, and it was in one of these pools near Spittal Pond that a half dozen or more pairs were found. A quantity of the spawn was secured and a series of eggs preserved.

Reptiles have at present very few representatives. There are no snakes, and the possible importation of them is carefully guarded against. The only land reptile is the Bermuda lizard (*Eumices longirostris*), which is not found elsewhere and is probably indigenous. Of turtles, four species, none of which is peculiar to Bermuda, are known to frequent the islands:—the green turtle (*Chelonia mydas*), the hawk bill (*Eretmochelys imbricata*), the logger-head (*Thalassochelys caouana*) and the trunk or leather turtle (*Sphargis coriacea*). The green turtle is still caught in nets in small numbers, but the others are found only occasionally. From the accounts of several of the early writers on Bermuda it is evident that some of the turtles (perhaps the green turtle) were once very abundant. Sylvanus Jourdan, writing of the shipwreck of Sir George Somers in 1609, says:

> There are also great store of Tortoises (which some call turtles), and those so great, that I have seene a bushell of egges in one of their bellies, which are sweeter than any Henne egge: and the Tortoise itselfe is all very goode meate, and yieldeth great store of oyle, which is as sweete as any butter: and one of them will suffice fifty men a meale at least: and of these hath beene taken great store, with two boates at the least forty in one day . . . We carried with vs also a good portion of Tortoise oyle, which either for frying or baking did vs very great pleasure, it being very sweete nourishing and wholesome.

An early account of their egg-laying, by Peter Martyr, is given in these words:

> At such time as the heate of Nature moueth them to generation, they come forthe of the Sea, and making a deepe pit in the sand, they lay three or foure hundred Egges therein: when they haue thus emptied their bag of Conception, they put as much of the same againe into the Pit as may satisfie to couer their Egges, and so resorte againe vnto the Sea, nothing carefull of their succession. At the day appointed of Nature to the procreation of these creatures there creepeth out a multitude of Tortoyses, as it were Pismyers out of an anthill, and this only by the heate of the Sunne, without any helpe of their Parents: their Egges are as big as Geese Egges, and themselues growne to perfection, bigger than great round Targets.

It is, however, the richness of the life in the sea—in marked contrast to the paucity of that on land—which is the chief source of attraction to the zoologist. If the gardens on the land require much attention and are the reflection of man's assiduity in transplanting the products of one country to the soil of another, the gardens of the sea demand no such care, and man has had little or nothing to do with shaping the wonderful display of marine life that carpets the floors of the broad lagoons and the reefs of the Bermuda plateau.

*(To be concluded.)*

# A STUDY OF THE DEVELOPMENT OF GEOMETRIC METHODS.*

By M. GASTON DARBOUX,

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TO appreciate the progress geometry has made during the century just ended, it is of advantage to cast a rapid glance over the state of mathematical science at the beginning of the nineteenth century.

We know that, in the last period of his life, Lagrange, fatigued by the researches in analysis and mechanics, which assured him, however, an immortal glory, neglected mathematics for chemistry, which, according to him, was easy as algebra, for physics, for philosophic speculations.

This mood of Lagrange we almost always find at certain moments of the life of the greatest savants. The new ideas which came to them in the fecund period of youth and which they introduced into the common domain have given them all they could have expected; they have fulfilled their task and feel the need of turning their mental activity towards wholly new subjects. This need, as we recognize, manifested itself with particular force at the epoch of Lagrange. At this moment, in fact, the program of researches opened to geometers by the discovery of the infinitesimal calculus appeared very nearly finished up. Some differential equations more or less complicated to integrate, some chapters to add to the integral calculus, and one seemed about to touch the very outmost bounds of science.

Laplace had achieved the explanation of the system of the world and laid the foundations of molecular physics. New ways opened before the experimental sciences and prepared the astonishing development they received in the course of the century just ended. Ampère, Poisson, Fourier and Cauchy himself, the creator of the theory of imaginaries, were occupied above all in studying the application of the analytic methods to mechanics, and seemed to believe that outside this new domain, which they hastened to cover, the outlines of theory and science were finally fixed.

Modern geometry, a glory we must claim for it, came, after the end of the eighteenth century, to contribute in large measure to the renewing of all mathematical science, by offering to research a way

* Read September 24, 1904, at the Congress of Arts and Science at St. Louis. Translated by Professor George Bruce Halsted.

new and fertile, and above all in showing us, by brilliant successes, that general methods are not everything in science, and that even in the simplest subject there is much for an ingenious and inventive mind to do.

The beautiful geometric demonstrations of Huygens, of Newton and of Clairaut were forgotten or neglected. The fine ideas introduced by Desargues and Pascal had remained without development and appeared to have fallen on sterile ground.

Carnot, by his 'Essai sur les transversales' and his 'Géométrie de position,' above all Monge, by the creation of descriptive geometry and by his beautiful theories on the generation of surfaces, came to renew a chain which seemed broken. Thanks to them, the conceptions of the inventors of analytic geometry, Descartes and Fermat, retook alongside the infinitesimal calculus of Leibnitz and Newton the place they had lost, yet should never have ceased to occupy. With his geometry, said Lagrange, speaking of Monge, this demon of a man will make himself immortal.

And, in fact, not only has descriptive geometry made it possible to coordinate and perfect the procedures employed in all the arts where precision of form is a condition of success and of excellence for the work and its products; but it appeared as the graphic translation of a geometry, general and purely rational, of which numerous and important researches have demonstrated the happy fertility.

Moreover, beside the 'Géométrie descriptive' we must not forget to place that other master-piece, the 'Application de l'analyse à la géométrie'; nor should we forget that to Monge are due the notion of lines of curvature and the elegant integration of the differential equation of these lines for the case of the ellipsoid, which, it is said, Lagrange envied him. To be stressed is this character of unity of the work of Monge.

The renewer of modern geometry has shown us from the beginning, what his successors have perhaps forgotten, that the alliance of geometry and analysis is useful and fruitful, that this alliance is perhaps for each a condition of success.

## II.

In the school of Monge were formed many geometers: Hachette, Brianchon, Chappuis, Binet, Lancret, Dupin, Malus, Gaultier de Tours, Poncelet, Chasles, etc. Among these Poncelet takes first rank. Neglecting, in the works of Monge, everything pertaining to the analysis of Descartes or concerning infinitesimal geometry, he devoted himself exclusively to developing the germs contained in the purely geometric researches of his illustrious predecessor.

Made prisoner by the Russians in 1813 at the passage of the

Dnieper and incarcerated at Saratoff, Poncelet employed the leisure captivity left him in the demonstration of the principles which he has developed in the 'Traité des propriétés projectives des figures,' issued in 1822, and in the great memoirs on reciprocal polars and on harmonic means, which go back nearly to the same epoch. So we may say the modern geometry was born at Saratoff.

Renewing the chain broken since Pascal and Desargues, Poncelet introduced at the same time homology and reciprocal polars, putting thus in evidence, from the beginning, the fruitful ideas on which the science has evolved during fifty years.

Presented in opposition to analytic geometry, the methods of Poncelet were not favorably received by the French analysts. But such were their importance and their novelty, that without delay they aroused, from divers sides, the most profound researches.

Poncelet had been alone in discovering the principles; on the contrary, many geometers appeared almost simultaneously to study them on all sides and to deduce from them the essential results which they implicitly contained.

At this epoch, Gergonne was brilliantly editing a periodical which has to-day for the history of geometry an inestimable value. The *Annales de Mathématiques,* published at Nîmes from 1810 to 1831. was during more than fifteen years the only journal in the entire world devoted exclusively to mathematical researches.

Gergonne, who, in many regards, was a model editor for a scientific journal, had the defects of his qualities; he collaborated, often against their will, with the authors of the memoirs sent him, rewrote them, and sometimes made them say more or less than they would have wished. Be that as it may, he was greatly struck by the originality and range of Poncelet's discoveries.

In geometry some simple methods of transformation of figures were already known; homology even had been employed in the plane, but without extending it to space, as did Poncelet, and especially without recognizing its power and fruitfulness. Moreover all these transformations were *punctual,* that is to say they made correspond a point to a point.

In introducing polar reciprocals, Poncelet was in the highest degree creative, because he gave the first example of a transformation in which to a point corresponded something other than a point.

Every method of transformation enables us to multiply the number of theorems, but that of polar reciprocals had the advantage of making correspond to a proposition another proposition of wholly different aspect. This was a fact essentially new. To put it in evidence, Gergonne invented the system, which since has had so much success, of memoirs printed in double columns with correlative

propositions in juxtaposition; and he had the idea of substituting for Poncelet's demonstrations, which required an intermediary curve or surface of the second degree, the famous 'principle of duality,' of which the signification, a little vague at first, was sufficiently cleared up by the discussions which took place on this subject between Gergonne, Poncelet and Pluecker.

Bobillier, Chasles, Steiner, Lamé, Sturm, and many others whose names escape me, were, at the same time as Pluecker and Poncelet, assiduous collaborators of the *Annales de Mathématiques*. Gergonne having become rector of the Acadamy of Montpellier, was forced to suspend in 1831 the publication of his journal. But the success it had obtained, the taste for research it had contributed to develop, had commenced to bear their fruit. Quetelet had established in Belgium the *Correspondance mathématique et physique*. Crelle, from 1826, brought out at Berlin the first sheets of his celebrated journal, where he published the memoirs of Abel, of Jacobi, of Steiner.

A great number of separate works began also to appear, wherein the principles of modern geometry were powerfully expounded and developed.

First came in 1827 the 'barycentrische Calcul' of Moebius, a work truly original, remarkable for the profundity of its conceptions, the elegance and the rigor of its exposition; then in 1828 the 'Analytisch-geometrische Entwickelungen' of Pluecker, of which the second part appeared in 1831 and which was soon followed by the 'System der analytischen Geometrie' of the same author published at Berlin in 1835.

In 1832 Steiner brought out at Berlin his great work: 'Systematische Entwickelung der Abhaengigkeit der geometrischen Gestalten von einander,' and, the following year, 'Die geometrischen Konstruktionen ausgefuehrt mittels der geraden Linie und eines festen Kreises,' where was confirmed by the most elegant examples a proposition of Poncelet's relative to the employment of a single circle for the geometric constructions.

Finally, in 1830, Chasles sent to the Academy of Brussels, which happily inspired had offered a prize for a study of the principles of modern geometry, his celebrated 'Aperçu historique sur l'origine et le développement des méthodes en géométrie,' followed by 'Mémoire sur deux principes généraux de la science: la dualité et l'homographie,' which was published only in 1837.

Time would fail us to give a worthy appreciation of these beautiful works and to apportion the share of each. Moreover, to what would such a study conduct us, but to a new verification of the general laws of the development of science. When the times are ripe, when the fundamental principles have been recognized and enunciated, nothing

stops the march of ideas; the same discoveries, or discoveries almost equivalent, appear at nearly the same instant, and in places the most diverse. Without undertaking a discussion of this sort, which, besides, might appear useless or become irritating, it is, however, of importance to bring out a fundamental difference between the tendencies of the great geometers who, about 1830, gave to geometry a scope before unknown.

III.

Some, like Chasles and Steiner, who consecrated their entire life to research in pure geometry, opposed what they called *synthesis* to *analysis* and, adopting in the ensemble if not in detail the tendencies of Poncelet, proposed to constitute an independent doctrine, rival of Descartes' analysis.

Poncelet could not content himself with the insufficient resources furnished by the method of projections; to attain imaginaries he created that famous *principle of continuity* which gave birth to such long discussions between him and Cauchy.

Suitably enunciated, this principle is excellent and can render great service. Poncelet was wrong in refusing to present it as a simple consequence of analysis; and Cauchy, on the other hand, was not willing to recognize that his own objections, applicable without doubt to certain transcendent figures, were without force in the applications made by the author of the 'Traité des propriétés projectives.'

Whatever be the opinion of such a discussion, it showed at least in the clearest manner that the geometric system of Poncelet rested on an analytic foundation, and besides we know, by the untoward publication of the manuscripts of Saratoff, that by the aid of Descartes' analysis were established the principles which serve as foundation for the 'Traité des propriétés projectives.'

Younger than Poncelet, who besides abandoned geometry for mechanics where his works had a preponderant influence, Chasles, for whom was created in 1847 a chair of *Géométric supérieure* in the Faculty of Science of Paris, endeavored to constitute a geometric doctrine entirely independent and autonomous. He has expounded it in two works of high importance, the 'Traité de géométrie supérieure,' which dates from 1852, and the 'Traité des sections coniques,' unhappily unfinished and of which the first part alone appeared in 1865.

In the preface of the first of these works he indicates very clearly the three fundamental points which permit the new doctrine to share the advantages of analysis and which to him appear to mark an advance in the cultivation of the science. These are: (1) The introduction of the principle of signs, which simplifies at once the enunciations and the demonstrations, and gives to Carnot's analysis of transversals all the scope of which it is susceptible; (2) the introduction of

imaginaries, which supplies the place of the principle of continuity and furnishes demonstrations as general as those of analytic geometry; (3) the simultaneous demonstration of propositions which are correlative, that is to say, which correspond in virtue of the principle of duality.

Chasles studies indeed in his work homography and correlation; but he avoids systematically in his exposition the employment of transformations of figures, which, he thinks, can not take the place of direct demonstrations since they mask the origin and the true nature of the properties obtained by their means.

There is truth in this judgment, but the advance itself of the science permits us to declare it too severe. If it happens often that, employed without discernment, transformations multiply uselessly the number of theorems, it must be recognized that they often aid us to better understand the nature of the propositions even to which they have been applied. Is it not the employment of Poncelet's projection which has led to the so fruitful distinction between projective properties and metric properties, which has taught us also the high importance of that cross ratio whose essential property is found already in Pappus, and of which the fundamental rôle has begun to appear after fifteen centuries only in the researches of modern geometry?

The introduction of the principle of signs was not as new as Chasles supposed at the time he wrote his 'Traité de Géométrie supérieure.'

Moebius, in his *barycentrische Calcul,* had already given issue to a *desideratum* of Carnot, and employed the signs in a way the largest and most precise, defining for the first time the sign of a segment and even that of an area.

Later he succeeded in extending the use of signs to lengths not laid off on the same straight and to angles not formed about the same point.

Besides Grassmann, whose mind has so much analogy to that of Moebius, had necessarily employed the principle of signs in the definitions which serve as basis for his methods, so original, of studying the properties of space.

The second characteristic which Chasles assigns to his system of geometry is the employment of imaginaries. Here, his method was really new and he illustrates it by examples of high interest. One will always admire the beautiful theories he has left us on homofocal surfaces of the second degree, where all the known properties and others new, as varied as elegant, flow from the general principle that they are inscribed in the same developable circumscribed to the circle at infinity.

But Chasles introduced imaginaries only by their symmetric func-

tions, and consequently would not have been able to define the cross ratio of four elements when these ceased to be real in whole or in part. If Chasles had been able to establish the notion of the cross ratio of imaginary elements, a formula he gives in the 'Géométrie supérieure' (p. 118 of the new edition) would have immediately furnished him that beautiful definition of angle as logarithm of a cross ratio which enabled Laguerre, our regretted confrère, to give the complete solution, sought so long, of the problem of the transformation of relations which contain at the same time angles and segments in homography and correlation.

Like Chasles, Steiner, the great and profound geometer, followed the way of pure geometry; but he has neglected to give us a complete exposition of the methods upon which he depended. However, they may be characterized by saying that they rest upon the introduction of those elementary geometric forms which Desargues had already considered, on the development he was able to give to Bobillier's theory of polars, and finally on the construction of curves and surfaces of higher degrees by the aid of sheaves or nets of curves of lower orders. In default of recent researches, analysis would suffice to show that the field thus embraced has just the extent of that into which the analysis of Descartes introduces us without effort.

## IV.

While Chasles, Steiner, and, later, as we shall see, von Staudt, were intent on constituting a rival doctrine to analysis and set in some sort altar against altar, Gergonne, Bobillier, Sturm, above all Pluecker, perfected the geometry of Descartes and constituted an analytic system in a manner adequate to the discoveries of the geometers.

It is to Bobillier and to Pluecker that we owe the method called *abridged notation*. Bobillier consecrated to it some pages truly new in the last volumes of the *Annales* of Gergonne.

Pluecker commenced to develop it in his first work, soon followed by a series of works where are established in a fully conscious manner the foundations of the modern analytic geometry. It is to him that we owe tangential coordinates, trilinear coordinates, employed with homogeneous equations, and finally the employment of canonical forms whose validity was recognized by the method, so deceptive sometimes, but so fruitful, called the *enumeration of constants*.

All these happy acquisitions infused new blood into Descartes' analysis and put it in condition to give their full signification to the conceptions of which the geometry called *synthetic* had been unable to make itself completely mistress.

Pluecker, to whom it is without doubt just to adjoin Bobillier, carried off by a premature death, should be regarded as the veritable

initiator of those methods of modern analysis where the employment of homogeneous coordinates permits treating simultaneously and, so to say, without the reader perceiving it, together with one figure all those deducible from it by homography and correlation.

## V.

Parting from this moment, a period opens brilliant for geometric researches of every nature.

The analysts interpret all their results and are occupied in translating them by constructions.

The geometers are intent on discovering in every question some general principle, usually undemonstrable without the aid of analysis, in order to make flow from it without effort a crowd of particular consequences, solidly bound to one another and to the principle whence they are derived. Otto Hesse, brilliant disciple of Jacobi, develops in an admirable manner that method of homogeneous coordinates to which Pluecker perhaps had not attached its full value. Boole discovers in the polars of Bobillier the first notion of a covariant; the theory of forms is created by the labors of Cayley, Sylvester, Hermite, Brioschi. Later Aronhold, Clebsch and Gordan and other geometers still living gave to it its final notation, established the fundamental theorem relative to the limitation of the number of covariant forms and so gave it all its amplitude.

The theory of surfaces of the second order, built up principally by the school of Monge, was enriched by a multitude of elegant properties, established principally by O. Hesse, who found later in Paul Serret a worthy emulator and continuer.

The properties of the polars of algebraic curves are developed by Pluecker and above all by Steiner. The study, already old, of curves of the third order is rejuvenated and enriched by a crowd of new elements. Steiner, the first, studies by pure geometry the double tangents of curves of the fourth order, and Hesse, after him, applies the methods of algebra to this beautiful question, as well as to that of points of inflection of curves of the third order.

The notion of *class* introduced by Gergonne, the study of a paradox in part elucidated by Poncelet and relative to the respective degrees of two curves reciprocal polars one of the other, give birth to the researches of Pluecker relative to the singularities called *ordinary* of algebraic plane curves. The celebrated formulas to which Pluecker is thus conducted are later extended by Cayley and by other geometers to algebraic skew curves, by Cayley again and by Salmon to algebraic surfaces.

The singularities of higher order are in their turn taken up by the geometers; contrary to an opinion then very widespread, Halphen

demonstrates that each of these singularities can not be considered as equivalent to a certain group of ordinary singularities and his researches close for a time this difficult and important question.

Analysis and geometry, Steiner, Cayley, Salmon, Cremona, meet in the study of surfaces of the third order, and, in conformity with the anticipations of Steiner, this theory becomes as simple and as easy as that of surfaces of the second order.

The algebraic ruled surfaces, so important for applications, are studied by Chasles, by Cayley, of whom we find the influence and the mark in all mathematical researches, by Cremona, Salmon, La Gournerie; so they will be later by Pluecker in a work to which we must return.

The study of the general surface of the fourth order would seem to be still too difficult; but that of the particular surfaces of this order with multiple points or multiple lines is commenced, by Pluecker for the surface of waves, by Steiner, Kummer, Cayley, Moutard, Laguerre, Cremona and many other investigators.

As for the theory of algebraic skew curves, grown rich in its elementary parts, it receives finally, by the labors of Halphen and of Noether, whom it is impossible for us here to separate, the most notable extensions.

A new theory with a great future is born by the labors of Chasles, of Clebsch and of Cremona; it concerns the study of all the algebraic curves which can be traced on a determined surface.

Homography and correlation, those two methods of transformation which have been the distant origin of all the preceding researches, receive from them in their turn an unexpected extension; they are not the only methods which make a single element correspond to a single element, as might have shown a particular transformation briefly indicated by Poncelet in the 'Traité des propriétés projectives.'

Pluecker defines the *transformation by reciprocal radii vectores* or *inversion,* of which Sir W. Thomson and Liouville hasten to show all the importance, as well for mathematical physics as for geometry.

A contemporary of Moebius and Pluecker, Magnus believed he had found the most general transformation which makes a point correspond to a point, but the researches of Cremona teach us that the transformation of Magnus is only the first term of a series of birational transformations which the great Italian geometer teaches us to determine methodically, at least for the figures of plane geometry.

The Cremona transformations long retained a great interest, though later researches have shown us that they reduce always to a series of successive applications of the transformation of Magnus.

## VI.

All the works we have enumerated, others to which we shall return later, find their origin and, in some sort, their first motive in the conceptions of modern geometry; but the moment has come to indicate rapidly another source of great advances for geometric studies. Legendre's theory of elliptic functions, too much neglected by the French geometers, is developed and extended by Abel and Jacobi. With these great geometers, soon followed by Riemann and Weierstrass, the theory of Abelian functions which, later, algebra would try to follow solely with its own resources, brought to the geometry of curves and surfaces a contribution whose importance will continue to grow.

Already, Jacobi had employed the analysis of elliptic functions in the demonstration of Poncelet's celebrated theorems on inscribed and circumscribed polygons, inaugurating thus a chapter since enriched by a multitude of elegant results; he had obtained also, by methods pertaining to geometry, the integration of Abelian equations.

But it was Clebsch who first showed in a long series of works all the importance of the notion of *deficiency* (Geschlecht, genre) of a curve, due to Abel and Riemann, in developing a crowd of results and elegant solutions that the employment of Abelian integrals would seem, so simple was it, to connect with their veritable point of departure.

The study of points of inflection of curves of the third order, that of double tangents of curves of the fourth order and, in general, the theory of osculation on which the ancients and the moderns had so often practised, were connected with the beautiful problem of the division of elliptic functions and Abelian functions.

In one of his memoirs, Clebsch had studied the curves which are *rational* or of deficiency zero; this led him, toward the end of his too short life, to envisage what may be called also *rational* surfaces, those which can be simply represented by a plane. This was a vast field for research, opened already for the elementary cases by Chasles, and in which Clebsch was followed by Cremona and many other savants. It was on this occasion that Cremona, generalizing his researches on plane geometry, made known not indeed the totality of birational transformations of space, but certain of the most interesting among these transformations.

The extension of the notion of deficiency to algebraic surfaces is already commenced; already also works of high value have shown that the theory of integrals, simple or mutiple, of algebraic differentials will find, in the study of surfaces as in that of curves, an ample field of important applications; but it is not proper for the reporter on geometry to dilate on this subject.

VII.

While thus were constituted the mixed methods whose principal applications we have just indicated, the pure geometers were not inactive. Poinsot, the creator of the theory of couples, developed, by a method purely geometric, 'that, said he, where one never for a moment loses from view the object of the research,' the theory of the rotation of a solid body that the researches of d'Alembert, Euler and Lagrange seemed to have exhausted; Chasles made a precious contribution to kinematic by his beautiful theorems on the displacement of a solid body, which have since been extended by other elegant methods to the case where the motion has divers degrees of freedom. He made known those beautiful propositions on attraction in general, which figure without disadvantage beside those of Green and Gauss.

Chasles and Steiner met in the study of the attraction of ellipsoids and showed thus once more that geometry has its designated place in the highest questions of the integral calculus.

Steiner did not disdain at the same time to occupy himself with the elementary parts of geometry. His researches on the contacts of circles and conics, on isoperimetric problems, on parallel surfaces, on the center of gravity of curvature, excited the admiration of all by their simplicity and their depth.

Chasles introduced his principle of correspondence between two variable objects which has given birth to so many applications; but here analysis re-took its place to study the principle in its essence, make it precise and generalize it.

It was the same concerning the famous theory of *characteristics* and the numerous researches of de Jonquières, Chasles, Cremona and still others, which gave the foundations of a new branch of the science, *Enumerative Geometry.*

During many years, the celebrated postulate of Chasles was admitted without any objection: a crowd of geometers believed they had established it in a manner irrefutable.

But, as Zeuthen then said, it is very difficult to recognize whether, in demonstrations of this sort, there does not exist always some weak point that their author has not perceived; and, in fact, Halphen, after fruitless efforts, crowned finally all these researches by clearly indicating in what cases the postulate of Chasles may be admitted and in what cases it must be rejected.

VIII.

Such are the principal works which restored geometric synthesis to honor and assured to it, in the course of the last century, the place belonging to it in mathematical research.

Numerous and illustrious workers took part in this great geometric movement, but we must recognize that its chiefs and leaders were Chasles and Steiner. So brilliant were their marvelous discoveries that they threw into the shade, at least momentarily, the publications of other modest geometers, less preoccupied perhaps in finding brilliant applications, fitted to evoke love for geometry, than to establish this science itself on an absolutely solid foundation.

Their works have received perhaps a recompense more tardy, but their influence grows each day; it will without doubt increase still more. To pass them over in silence would be without doubt to neglect one of the principal factors which will enter into future researches.

We allude at this moment above all to von Staudt. His geometric works were published in two books of grand interest: the 'Geometrie der Lage,' issued in 1847, and the 'Beiträge zur Geometrie der Lage,' published in 1856, that is to say, four years after the 'Géométrie supérieure.'

Chasles, as we have seen, had devoted himself to constituting a body of doctrine independent of Descartes' analysis and had not completely succeeded. We have already indicated one of the criticisms that can be made upon this system: the imaginary elements are there defined only by their symmetric functions, which necessarily excludes them from a multitude of researches. On the other hand, the constant employment of cross ratio, of transversals and of involution, which requires frequent analytic transformations, gives to the 'Géométrie supérieure' a character almost exclusively metric which removes it notably from the methods of Poncelet. Returning to these methods, von Staudt devoted himself to constituting a geometry freed from all metric relation and resting exclusively on relations of situation.

This is the spirit in which was conceived his first work, the 'Geometrie der Lage' of 1847. The author there takes as point of departure the harmonic properties of the complete quadrilateral and those of homologic triangles, demonstrated uniquely by considerations of geometry of three dimensions, analogous to those of which the School of Monge made such frequent use.

In this first part of his work, von Staudt neglected entirely imaginary elements. It is only in the *Beiträge,* his second work, that he succeeds, by a very original extension of the method of Chasles, in defining geometrically an isolated imaginary element and distinguishing it from its conjugate.

This extension, although rigorous, is difficult and very abstract. It may be defined in substance as follows: Two conjugate imaginary points may always be considered as the double points of an involution on a real straight; and just as one passes from an imaginary to its conjugate by changing $i$ into $-i$, so one may distinguish the two

imaginary points by making correspond to each of them one of the two different senses which may be attributed to the straight. In this there is something a little artificial; the development of the theory erected on such foundations is necessarily complicated. By methods purely projective, von Staudt establishes a calculus of cross ratios of the most general imaginary elements. Like all geometry, the projective geometry employs the notion of order and order engenders number; we are not astonished therefore that von Staudt has been able to constitute his calculus; but we must admire the ingenuity displayed in attaining it. In spite of the efforts of distinguished geometers who have essayed to simplify its exposition, we fear that this part of the geometry of von Staudt, like the geometry otherwise so interesting of the profound thinker Grassmann, can not prevail against the analytic methods which have won to-day favor almost universal.

Life is short; geometers know and also practise the principle of least action. Despite these fears, which should discourage no one, it seems to us that under the first form given it by von Staudt, projective geometry must become the necessary companion of descriptive geometry, that it is called to renovate this geometry in its spirit, its procedures and its applications.

This has already been comprehended in many countries, and notably in Italy where the great geometer Cremona did not disdain to write, for the schools, an elementary treatise on projective geometry.

## IX.

In the preceding articles, we have essayed to follow and bring out clearly the most remote consequences of the methods of Monge and Poncelet. In creating tangential coordinates and homogeneous coordinates, Pluecker seemed to have exhausted all that the method of projections and that of reciprocal polars could give to analysis.

It remained for him, toward the end of his life, to return to his first researches to give them an extension enlarging to an unexpected degree the domain of geometry.

Preceded by innumerable researches on systems of straight lines, due to Poinsot, Moebius, Chasles, Dupin, Malus, Hamilton, Kummer, Transon, above all to Cayley, who first introduced the notion of the coordinates of the straight, researches originating perhaps in statics and kinematics, perhaps in geometrical optics, Pluecker's geometry of the straight line will always be regarded as the part of his work where are met the newest and most interesting ideas.

That Pluecker first set up a methodic study of the straight line, that already is important, but that is nothing beside what he discovered. It is sometimes said that the principle of duality shows that

the plane as well as the point may be considered as a space element. That is true; but in adding the straight line to the plane and point as possible space element, Pluecker was led to recognize that any curve, any surface, may also be considered as space element, and so was born a new geometry which already has inspired a great number of works, which will raise up still more in the future.

A beautiful discovery, of which we shall speak further on, has already connected the geometry of spheres with that of straight lines and permits the introduction of the notion of coordinates of a sphere.

The theory of systems of circles is already commenced; it will be developed without doubt when one wishes to study the representation, which we owe to Laguerre, of an imaginary point in space by an oriented circle.

But before expounding the development of these new ideas which have vivified the infinitesimal methods of Monge, it is necessary to go back to take up the history of branches of geometry that we have neglected until now.

## X.

Among the works of the school of Monge, we have hitherto confined ourselves to the consideration of those connected with *finite* geometry; but certain of the disciples of Monge devoted themselves above all to developing the new notions of infinitesimal geometry applied by their master to curves of double curvature, to lines of curvature, to the generation of surfaces, notions expounded at least in part in the 'Application de l'Analyse à la Géométrie.' Among these we must cite Lancret, author of beautiful works on skew curves, and above all Charles Dupin, the only one perhaps who followed all the paths opened by Monge

Among other works, we owe to Dupin two volumes Monge would not have hesitated to sign: the 'Développements de Géométrie pure,' issued in 1813 and the 'Applications de Géométrie et de Méchanique,' dating from 1822.

There we find the notion of *indicatrix,* which was to renovate, after Euler and Meunier, all the theory of curvature, that of conjugate tangents, of asymptotic lines which have taken so important a place in recent researches. Nor should we forget the determination of the surface of which all the lines of curvature are circles, nor above all the memoir on triple systems of orthogonal surfaces where is found, together with the discovery of the triple system formed by surfaces of the second degree, the celebrated theorem to which the name of Dupin will remain attached.

Under the influence of these works and of the renaissance of synthetic methods, the geometry of infinitesimals re-took in all researches the place Lagrange had wished to take away from it forever.

Singular thing, the geometric methods thus restored were to receive the most vivid impulse in consequence of the publication of a memoir which, at least at first blush, would appear connected with the purest analysis; we mean the celebrated paper of Gauss: 'Disquisitiones generales circa superficies curvas' which was presented in 1827 to the Göttingen Society, and whose appearance marked, one may say, a decisive date in the history of infinitesimal geometry.

From this moment, the infinitesimal method took in France a free scope before unknown.

Frenet, Bertrand, Molins, J. A. Serret, Bouquet, Puiseux, Ossian Bonnet, Paul Serret, develop the theory of skew curves. Liouville, Chasles, Minding, join them to pursue the methodic study of the memoir of Gauss.

The integration made by Jacobi of the differential equation of the geodesic lines of the ellipsoid started a great number of researches. At the same time the problems studied in the 'Application de l'Analyse' of Monge were greatly developed.

The determination of all the surfaces having their lines of curvature plane or spheric completed in the happiest manner certain partial results already obtained by Monge.

At this moment, one of the most penetrating of geometers, according to the judgment of Jacobi, Gabriel Lamé, who, like Charles Sturm, had commenced with pure geometry and had already made to this science contributions the most interesting by a little book published in 1817 and by memoirs inserted in the *Annales* of Gergonne, utilized the results obtained by Dupin and Binet on the system of confocal surfaces of the second degree and, rising to the idea of curvilinear coordinates in space, became the creator of a wholly new theory destined to receive in mathematical physics the most varied applications.

## XI.

Here again, in this infinitesimal branch of geometry are found the two tendencies we have pointed out *à propos* of the geometry of finite quantities.

Some, among whom must be placed J. Bertrand and O. Bonnet, wish to constitute an independent method resting directly on the employment of infinitesimals. The grand 'Traité de Calcul différentiel,' of Bertrand, contains many chapters on the theory of curves and of surfaces, which are, in some sort, the illustration of this conception.

Others follow the usual analytic ways, being only intent to clearly recognize and put in evidence the elements which figure in the first plan. Thus did Lamé in introducing his theory of *differential parameters.* Thus did Beltrami in extending with great ingenuity the employment of these differential invariants to the case of two independent variables, that is to say, to the study of surfaces.

It seems that to-day is accepted a mixed method whose origin is found in the works of Ribaucour, under the name *périmorphie.* The rectangular axes of analytic geometry are retained, but made mobile and attached as seems best to the system to be studied. Thus disappear most of the objections which have been made to the method of coordinates. The advantages of what is sometimes called *intrinsic* geometry are united to those resulting from the use of the regular analysis. Besides, this analysis is by no means abandoned; the complications of calculation which it almost always carries with it, in its applications to the study of surfaces and rectilinear coordinates, usually disappear if one employs the notion on the invariants and the covariants of quadratic powers of differentials which we owe to the researches of Lipschitz and Christoffel, inspired by Riemann's studies on the non-Euclidean geometry.

XII.

The results of so many labors were not long in coming. The notion of geodesic curvature which Gauss already possessed, but without having published it, was given by Bonnet and Liouville, the theory of surfaces of which the radii of curvature are functions one of the other, inaugurated in Germany by two propositions which would figure without disadvantage in the memoir of Gauss, was enriched by Ribaucour, Halphen, S. Lie and others, with a multitude of propositions, some concerning these surfaces envisaged in a general manner; others applying to particular cases where the relation between the radii of curvature takes a form particularly simple; to minimal surfaces for example, and also to surfaces of constant curvature, positive or negative.

The minimal surfaces were the object of works which make of their study the most attractive chapter of infinitesimal geometry. The integration of their partial differential equation constitutes one of the most beautiful discoveries of Monge; but because of the imperfection of the theory of imaginaries, the great geometer could not get from its formulas any mode of generation of these surfaces, nor even any particular surface. We will not here retrace the detailed history which we have presented in our 'Leçons sur la théorie des surfaces'; but it is proper to recall the fundamental researches of Bonnet which have given us, in particular, the notion of *surfaces associated with a given surface,* the formulas of Weierstrass which establish a close bond between the minimal surfaces and the functions of a complex variable, the researches of Lie by which it was established that just the formulas of Monge can to-day serve as foundation for a fruitful study of minimal surfaces.

In seeking to determine the minimal surfaces of smallest classes or degrees, we were led to the notion of double minimal surfaces which is dependent on *Analysis situs.*

Three problems of unequal importance have been studied in this theory.

The first, relative to the determination of minimal surfaces inscribed along a given contour in a developable equally given, was solved by celebrated formulas which have led to a great number of propositions. For example, every straight traced on such a surface is an axis of symmetry.

The second, set by S. Lie, concerns the determination of all the algebraic minimal surfaces inscribed in an algebraic developable, without the curve of contact being given. It also has been entirely elucidated.

The third and the most difficult is what the physicists solve experimentally, by plunging a closed contour into a solution of glycerine. It concerns the determination of the minimal surface passing through a given contour.

The solution of this problem evidently surpasses the resources of geometry. Thanks to the resources of the highest analysis, it has been solved for particular contours in the celebrated memoir of Riemann and in the profound researches which have followed or accompanied this memoir.

For the most general contour, its study has been brilliantly begun, it will be continued by our successors.

After the minimal surfaces, the surfaces of constant curvature attracted the attention of geometers. An ingenious remark of Bonnet connects with each other the surfaces of which one or the other of the two curvatures, mean curvature or total curvature, is constant.

Bour announced that the partial differential equation of surfaces of constant curvature could be completely integrated. This result has not been recovered; it would seem even very doubtful if we consider a research where S. Lie has essayed in vain to apply a general method of integration of partial differential equations to the particular equation of surfaces of constant curvature.

But, if it is impossible to determine in finite terms all these surfaces, it has at least been possible to obtain certain of them, characterized by special properties, such as that of having their lines of curvature plane or spheric; and it has been shown, by employing a method which succeeds in many other problems, that from every surface of constant curvature may be derived an infinity of other surfaces of the same nature, by employing operations clearly defined which require only quadratures.

The theory of the deformation of surfaces in the sense of Gauss has been also much enriched. We owe to Minding and to Bour the detailed study of that special deformation of ruled surfaces which leaves the generators rectilineal. If we have not been able, as has

been said, to determine the surfaces applicable on the sphere, other surfaces of the second degree have been attacked with more success, and, in particular, the paraboloid of revolution.

The systematic study of the deformation of general surfaces of the second degree is already entered upon; it is one of those which will give shortly the most important results.

The theory of infinitesimal deformation constitutes to-day one of the most finished chapters of geometry. It is the first somewhat extended application of a general method which seems to have a great future.

Being given a system of differential or partial differential equations, suitable to determine a certain number of unknowns, it is advantageous to associate with it a system of equations which we have called *auxiliary system* and which determines the systems of solutions infinitely near any given system of solutions. The auxiliary system being necessarily linear, its employment in all researches gives precious light on the properties of the proposed system and on the possibility of obtaining its integration.

The theory of lines of curvature and of asymptotic lines has been notably extended. Not only have been determined these two series of lines for particular surfaces such as the tetrahedral surfaces of Lamé; but also, in developing Moutard's results relative to a particular class of linear partial differential equations of the second order, it proved possible to generalize all that had been obtained for surfaces with lines of curvature plane or spheric, in determining completely all the classes of surfaces for which could be solved the problem of *spheric representation*.

Just so has been solved the correlative problem relative to asymptotic lines in making known all the surfaces of which the infinitesimal deformation can be determined in finite terms. Here is a vast field for research whose exploration is scarcely begun.

The infinitesimal study of rectilinear congruences, already commenced long ago by Dupin, Bertrand, Hamilton, Kummer, has come to intermingle in all these researches. Ribaucour, who has taken in it a preponderant part, studied particular classes of rectilinear congruences and, in particular, the congruences called *isotropes*, which intervene in the happiest way in the study of minimal surfaces.

The triply orthogonal systems which Lamé used in mathematical physics have become the object of systematic researches. Cayley was the first to form the partial differential equation of the third order on which the general solution of this problem was made to depend.

The system of homofocal surfaces of the second degree has been generalized and has given birth to that theory of general *cyclides* in which may be employed at the same time the resources of metric

geometry, of projective geometry and of infinitesimal geometry. Many other orthogonal systems have been made known. Among these it is proper to signalize the *cyclic* systems of Ribaucour, for which one of the three families admits circles as orthogonal trajectories, and the more general systems for which these orthogonal trajectories are simply plane curves.

The systematic employment of imaginaries, which we must be careful not to exclude from geometry, has permitted the connection of all these determinations with the study of the finite deformation of a particular surface.

Among the methods which have permitted the establishment of all these results it is proper to note the systematic employment of linear partial differential equations of the second order and of systems formed of such equations. The most recent researches show that this employment is destined to renovate most of the theories.

Infinitesimal geometry could not neglect the study of the two fundamental problems set it by the calculus of variations.

The problem of the shortest path on a surface was the object of masterly studies by Jacobi and by Ossian Bonnet. The study of geodesic lines has been followed up; we have learned to determine them for new surfaces. The theory of ensembles has come to permit the following of these lines in their course on a given surface.

The solution of a problem relative to the representation of two surfaces one on the other has greatly increased the interest of discoveries of Jacobi and of Liouville relative to a particular class of surfaces of which the geodesic lines could be determined. The results concerning this particular case led to the examination of a new question: to investigate all the problems of the calculus of variations of which the solution is given by curves satisfying a given differential equation.

Finally, the methods of Jacobi have been extended to space of three dimensions and applied to the solution of a question which presented the greatest difficulties: the study of properties of minimum appertaining to the minimal surface passing through a given contour.

## XIII.

Among the inventors who have contributed to the development of infinitesimal geometry, Sophus Lie distinguishes himself by many capital discoveries which place him in the first rank.

He was not one of those who show from infancy the most characteristic aptitudes, and at the moment of quitting the University of Christiania in 1865, he still hesitated between philology and mathematics.

It was the works of Pluecker which gave him for the first time full consciousness of his veritable calling.

He published in 1869 a first work on the interpretation of imaginaries in geometry, and from 1870 he was in possession of the directing ideas of his whole career. I had at this epoch the pleasure of seeing him often, of entertaining him at Paris, where he had come with his friend F. Klein.

A course by M. Sylow followed by Lie had revealed to him all the importance of the theory of substitutions; the two friends studied this theory in the great treatise of C. Jordan; they were fully conscious of the important rôle it was called on to play in so many branches of mathematical science where it had not yet been applied.

They have both had the good fortune to contribute by their works to impress upon mathematical studies the direction which to them appeared the best.

In 1870, Sophus Lie presented to the Academy of Sciences of Paris a discovery extremely interesting. Nothing bears less resemblance to a sphere than a straight line, and yet Lie had imagined a singular transformation which made a sphere correspond to a straight, and permitted, consequently, the connecting of every proposition relative to straights with a proposition relating to spheres and *vice versa*.

In this so curious method of transformation, each property relative to the lines of curvature of a surface furnishes a proposition relative to the asymptotic lines of the surface attained.

The name of Lie will remain attached to these deep-lying relations which join to one another the straight line and the sphere, those two essential and fundamental elements of geometric research. He developed them in a memoir full of new ideas which appeared in 1872.

The works which followed this brilliant début of Lie fully confirmed the hopes it had aroused. Pluecker's conception relative to the generation of space by straight lines, by curves or surfaces arbitrarily chosen, opens to the theory of algebraic forms a field which has not yet been explored, that Clebsch scarcely began to recognize and settle the boundaries of. But, from the side of infinitesimal geometry, this conception has been given its full value by Sophus Lie. The great Norwegian geometer was able to find in it first the notion of congruences and complexes of curves, and afterward that of *contact transformations* of which he had found, for the case of the plane, the first germ in Pluecker. The study of these transformations led him to perfect, at the same time with M. Mayer, the methods of integration which Jacobi had instituted for partial differential equations of the first order; but above all it threw the most brilliant light on the most difficult and the most obscure parts of the theories relative to partial differential equations of higher order. It permitted Lie, in particular, to indicate all the cases in which the method of characteristics of Monge is fully applicable to equations of the second order with two independent variables.

In continuing the study of these special transformations, Lie was led to construct progressively his masterly theory of continuous groups of transformations and to put in evidence the very important rôle that the notion of group plays in geometry. Among the essential elements of his researches, it is proper to signalize the infinitesimal transformations, of which the idea belongs exclusively to him.

Three great books published under his direction by able and devoted collaborators contain the essential part of his works and their applications to the theory of integration, to that of complex units and to the non-Euclidean geometry.

## XIV.

By an indirect way I have arrived at that non-Euclidean geometry of which the study takes in the researches of geometers a place which grows greater each day.

If I were the only one to talk with you about geometry, I would take pleasure in recalling to you all that has been done on this subject since Euclid or at least from Legendre to our days.

Envisaged successively by the greatest geometers of the last century, the question has progressively enlarged.

It commenced with the celebrated *postulatum* relative to parallels; it ends with the totality of geometric axioms.

The 'Elements' of Euclid, which have withstood the action of so many centuries, will have at least the honor before ending of arousing a long series of works admirably enchained which will contribute, in the most effective way, to the progress of mathematics, at the same time that they furnish to the philosophers the points of departure the most precise and the most solid for the study of the origin and of the formation of our cognitions.

I am assured in advance that my distinguished collaborator will not forget, among the problems of the present time, this one, which is perhaps the most important, and with which he has occupied himself with so much success; and I leave to him the task of developing it with all the amplitude which it assuredly merits.

I have just spoken of the elements of geometry. They have received in the last hundred years extensions which must not be forgotten. The theory of polyhedrons has been enriched by the beautiful discoveries of Poinsot on the star polyhedrons and those of Moebius on polyhedrons with a single face. The methods of transformation have enlarged the exposition. We may say to-day that the first book contains the theory of translation and of symmetry, that the second amounts to the theory of rotation and of displacement, that the third rests on homothety and inversion. But it must be recognized that it is thanks to analysis that the 'Elements' have been enriched by their most beautiful propositions.

It is to the highest analysis we owe the inscription of regular polygons of 17 sides and analogous polygons. It is to it we owe the demonstrations so long sought, of the impossibility of the quadrature of the circle, of the impossibility of certain geometric constructions with the aid of the ruler and the compasses. It is to it finally that we owe the first rigorous demonstrations of the properties of maximum and of minimum of the sphere. It will appertain to geometry to enter upon this ground where analysis has preceded it.

What will be the elements of geometry in the course of the century which has just commenced? Will there be a single elementary book of geometry? It is perhaps America, with its schools free from all program and from all tradition, which will give us the best solution of this important and difficult question.

Von Staudt has sometimes been called the *Euclid of the nineteenth century;* I would prefer to call him the *Euclid of projective geometry;* but that geometry, however interesting it may be, is it destined to furnish the unique foundation of the future elements?

## XV.

The moment has come to close this over-long recital, and yet there is a crowd of interesting researches that I have been, so to say, forced to neglect.

I should have loved to talk with you about those geometries of any number of dimensions of which the notion goes back to the first days of algebra, but of which the systematic study was commenced only sixty years ago by Cayley and by Cauchy. This kind of researches has found favor in your country and I need not recall that our illustrious president, after having shown himself the worthy successor of Laplace and Le Verrier, in a space which he considers with us as being endowed with three dimensions, has not disdained to publish, in the *American Journal,* considerations of great interest on the geometries of $n$ dimensions.

A single objection can be made to studies of this sort, and was already formulated by Poisson: the absence of all real foundation, of all *substratum* permitting the presentation, under aspects visible and in some sort palpable, of the results obtained.

The extension of the methods of descriptive geometry, and above all the employment of Pluecker's conceptions on the generation of space, will contribute to take away from this objection much of its force.

I would have liked to speak to you also of the method of equipollences, of which we find the germ in the posthumous works of Gauss, of Hamilton's quaternions, of Grassmann's methods and in general of systems of complex units, of the *Analysis situs,* so intimately connected with the theory of functions, of the geometry called *kinematic,*

of the theory of abaci, of geometrography, of the applications of geometry to natural philosophy or to the arts. But I fear, if I branched out beyond measure, some analyst, as has happened before, would accuse geometry of wishing to monopolize everything.

My admiration for analysis, grown so fruitful and so powerful in our time, would not permit me to conceive such a thought. But, if some reproach of this sort could be formulated to-day, it is not to geometry, it is to analysis it would be proper, I believe, to address it. The circle in which the mathematical studies appeared to be enclosed at the beginning of the nineteenth century has been broken on all sides.

The old problems present themselves to us under a new form, new problems offer themselves, whose study occupies legions of workers.

The number of those who cultivate pure geometry has become prodigiously restricted. Therein is a danger against which it is important to provide. We must not forget that, if analysis has acquired means of investigation which it lacked heretofore, it owes them in great part to the conceptions introduced by the geometers. Geometry must not remain in some sort entombed in its triumph. It is in its school we have learned; our successors must learn never to be blindly proud of methods too general, to envisage the questions in themselves and to find, in the conditions particular to each problem, perhaps a direct way towards a solution, perhaps the means of applying in an appropriate manner the general procedures which every science should gather.

As Chasles said at the beginning of the 'Aperçu historique': 'The doctrines of pure geometry offer often, and in a multitude of questions, that way simple and natural which, penetrating to the very source of the truths, lays bare the mysterious chain which binds them to each other and makes us know them individually in the way most luminous and most complete.'

Cultivate therefore geometry, which has its own advantages, without wishing, on all points, to make it equal to its rival.

For the rest, if we were tempted to neglect it, it would soon find in the applications of mathematics, as it did once before, means to rise up again and develop itself anew. It is like the giant Anteus who recovered his strength in touching the earth.

# SOME PRESENT PROBLEMS IN TECHNICAL CHEMISTRY.*

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TECHNICAL chemistry may be regarded as the performance of a chemical reaction or series of reactions on a scale sufficiently large and by a method sufficiently economical to enable the product to be sold at a profit. The problems which confront the investigators in this field of endeavor may, therefore, be divided into two classes according as they pertain to the chemical reaction involved, or to the process to be employed in carrying on this reaction. The first division is pure chemistry, even though the results of the solution be utilitarian; the second is chemical engineering. Although in the program of this congress the utilitarian side of chemistry is widely separated from the subject of general chemistry, there is in reality no dividing line between the two. It would be difficult to find an investigator in the field of pure science who does not hope, and indeed believe, that the results of his labor will at some time prove of value to humanity; may ultimately be utilitarian. On the other hand, few if any chemical manufacturers would admit that in solving their chemical problems they do not utilize the most scientific methods at their command. The research assistant is in the last analysis utilitarian; while the successful chemical engineer is preeminently scientific.

Probably in no country have the problems confronting the chemical industries been so successfully met as in Germany; yet Germany does not excel in chemical engineers. Engineering enterprises—mechanical, civil and electrical, as well as chemical—are carried on as successfully in England and America as they are in Germany; and still the latter leads the world in her chemical manufactures. The explanation for this lies in the fact that Germany pays the greatest attention to the first class of problems, as above divided, and recognizes that pure chemistry is inseparably connected with her industries; that the application of new facts and principles follows rapidly when once these facts and principles are known. Most of the problems in technical chemistry are first considered problems in pure chemistry and studied in accordance with recognized methods of modern research by men fully trained in pure science. If these men are also chemical engineers, the

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ultimate solution of the problem is proportionately hastened; but they are first of all men trained in the spirit and methods of scientific research.

In general, an investigation may be prompted by either or both of two incentives; either by the pleasure to be derived from achievement and the love of scientific study for itself, or by the hope that from the investigation some immediately useful result may be obtained. Yet between the product of the first motive—pure chemistry—and the ultimate result of the second—technical chemistry—a difference does not necessarily exist. The fact that a piece of work is undertaken and carried on with the predetermined purpose of applying the results to a practical or commercial end does not in itself render it any the less a study in pure chemistry. The method of thought and action employed will be that of the investigator in pure science whatever the ultimate object may be. To make the result of the work an achievement in technical chemistry an important contribution must then be made by the chemical engineer, in order that the conditions making up the definition of the term 'technical chemistry' as already stated may be fulfilled.

In trying to point out, therefore, some of the important problems in technical chemistry, no attempt will be made to distinguish between the part which must first be played by pure chemistry in their solution, and that which will still remain to be done by the chemical engineer to make this contribution utilitarian.

There is always a tendency to measure the importance of a subject by the extent of one's knowledge of it and the depth of the interest one has in it. In order, therefore, that we may obtain a proper perspective, we must consider a problem important in proportion as it affects the greatest number of people; of moment according as the results of its solution will be far-reaching in their effects, or be but of local benefit.

From this point of view, the first industry to demand attention is the manufacture of fertilizers. In the last ten years the product of this industry in the United States alone has increased from 1,900,000 tons to 2,900,000 tons, an increase of over 50 per cent. This increase is probably more marked in America than in the older countries of Europe, because the necessity of replenishing the virgin soil was there reached long ago, while with us it is only begun. The magnitude of the industries which are dependent directly or indirectly upon agricultural products is so well recognized that it needs no discussion here. That the supply of crude material from which plant life derives its nourishment should be maintained is therefore a source of responsibility for the present as well as for future generations. Of this as of every great industry it may be said that the supply of raw material for to-morrow is a problem for to-day.

Dr. H. W. Wiley, of the U. S. Department of Agriculture, has pointed out the surprisingly large amount of potash, phosphoric acid and nitrogen which is yearly taken up by the agricultural crops alone. The average percentage of ash in all the important crops has been accurately determined and their percentage composition in respect to potash and phosphoric acid is known. In addition to this we have a satisfactory knowledge of the percentage of albuminous matter contained in the more important agricultural products. From these figures and the reports of the U. S. Department of Agriculture we can calculate the amount of potash, phosphoric acid and nitrogen consumed each year. Allowing a value of four cents a pound for potash, five cents for phosphoric acid and twelve cents for nitrogen, the total value of these ingredients for a single year amounts to the enormous sum of $3,200,000,000. To be sure, this is not all removed from the farm and lost to the soil; but that which remains in the form of straw and manure is but a small percentage of the whole. Straw is generally burned, while the soluble salts of the manure heaps are often allowed to leach out and go to waste. When, in addition, we consider the terrible waste involved in the modern methods of sewage disposal, where, instead of being returned to the soil, these valuable constituents are carried to the ocean, the net loss of these chemicals can be easily appreciated.

Of these three most important ingredients making up a fertilizer for general purposes, phosphoric acid alone seems to be at hand in practically inexhaustible quantities. Slag rich in phosphoric acid from certain metallurgical processes is already much used as a source of this material. Fresh deposits of phosphate rock of such enormous extent are being brought to light almost every day that our supply of this material may give us little immediate concern.

Although the Strassfurt region of Germany may continue to ship undiminished quantities of potash salts, the second important ingredient of a fertilizer, the world's supply can not be said to be on a perfectly satisfactory basis until independent sources are developed. In the year 1902 the value of the potash salts imported into the United States amounted to four and a half million dollars. The recovery of potash from wood ashes, while once an important industry, must diminish as the value of hard wood increases. While there are doubtless natural beds of potassium salt still to be discovered, the time seems rapidly approaching when we should render more readily available the great amount of potassium distributed throughout the mineral kingdom. Rhodin had already accomplished much towards this end when he showed that feldspar could be made to yield the greater part of its potash when it was heated with lime and common salt. Clark has found that when the mineral leucite with its 21 per cent. potassium

oxide is heated with ammonium chloride, the potassium is converted into chloride and is easily separated from the melt. If this reaction could be extended to orthoclase and the ammonia recovered by treatment with lime, the enormous quantity of potash contained in this mineral would be at our service.

It is, however, to the supply of available nitrogen that the greatest importance attaches. The sodium nitrate producing countries of South America exported last year 1,300,000 tons, a large percentage of which came to America. Egypt and the southwestern United States have nitrate deposits, but of their extent and value little is as yet known. Of the other form of available nitrogen, ammonia, our main supply is at present from the destructive distillation of coal. Although the introduction of by-product coke ovens has increased this supply, our domestic production is now not over 40,000 tons a year.

In the atmosphere, however, we have a never-failing source of nitrogen which needs only to be converted into other forms to be of the greatest value. It is interesting to note that even as long ago as 1840 this same problem was the subject of considerable experimentation and the basis of several technical processes. In this year there was erected in France a plant for the manufacture of potassium ferrocyanide which depended on the atmosphere for the supply of nitrogen, and which at one time turned out almost a ton of product per day. From this time until the present, the utilization of this inexpensive and inexhaustible supply of raw material has been an attractive field and has held the attention of many investigators. It had long been known that while carbon and nitrogen alone could not be made to unite, the union was effected when these elements were brought together in the presence of a strong alkali. The technical difficulties in the way of successfully applying this reaction seem to have been the rapid destruction of the retorts and the loss of alkali through volatilization. With the advent of cheap electricity and the consequent development of the electric furnace, this idea was made the basis of further work. The destruction of the retorts was largely overcome by generating the heat within the apparatus rather than without. When a non-volatile alkali was used to eliminate the loss from this source and a higher temperature maintained, it was found that a carbide was formed as an intermediate product and that nitrogen readily reacted with the carbon thus held in combination.

Among the investigators who have thus far taken advantage of this reaction may be mentioned the Ampere Chemical Company, located at Niagara Falls, and the group of men represented by the Siemens and Halske Company, of Berlin. The former first produces a carbide of barium and then converts it into barium cyanide by passing over it air from which the oxygen has either been removed or converted into

carbon monoxide. Robert Bunsen long ago showed that by using steam the nitrogen in an alkaline cyanide may be converted into ammonia. In this case barium oxide would be left to be returned to the furnace and to continue the cycle. When advantage is taken of the process discovered by Professor Ostwald, by which ammonia is converted into nitric acid through the medium of a catalyzing or contact agent, the production of nitrates by way of the cyanide reaction is easily foreseen.

The Siemens and Halske Company prepared in addition to cyanide and ammonia by use of the carbide-nitrogen reaction a new compound in technical chemistry, calcium cyanamide. In contradistinction to cyanides the nitrogen of this compound is available for plant food and can take the place of the more common nitrogen salts in commercial fertilizers. The technical difficulties in the way of the economic application of these processes are doubtless very great, but when one considers the advance which has been made in the last five years he has ample reasons to believe that it will not be a great while before the synthetic preparation of the cyanides, ammonia and nitric acid from atmospheric nitrogen will be on a commercial basis.

The old reaction by which nitrogen and oxygen were made to unite through the agency of a high potential electric discharge has been made the basis of a process for the manufacture of nitric acid by the Atmospheric Products Company, operating at Niagara Falls. For agricultural purposes it is proposed to absorb the nitric acid thus formed in milk of lime and so produce an exceptionally cheap product. There still remains much to be done before this can be called a technical process.

A very much less technical, but so far as our knowledge at present goes, a more promising method of fixing atmospheric nitrogen in the form of nitrates, is through the agency of bacteria. While it is true that one group of bacteria has the power of breaking down nitrates with the production of nitrogen gas, there are other groups which are equally able to absorb elementary nitrogen with the production of nitrates. A great deal of excellent work has recently been done by the U. S. Department of Agriculture, with the result that cultures for the artificial inoculation of the soil may now be obtained in considerable quantity. It has been found that these bacteria when grown upon nitrogen-free media may be dried without losing their high activity. When immersed in water they are easily revived. A dry culture similar to a yeast-cake and of about the same size can thus be sent out and used to prepare a fluid in which the original nitrogen fixing bacteria may be multiplied sufficiently to inoculate a number of acres of land. The amount of material thus obtained is limited only by the quantity of the nutrient water solution used in increasing the

germs. Field experiments have shown the wonderful activity of these bacteria in fixing atmospheric nitrogen and the splendid crops which may be grown upon what would otherwise be almost sterile soil.

In this one problem of our future supply of available nitrogen for agriculture as well as general manufacturing purposes, we note the aid which technical chemistry draws from the other departments of natural science. The electrical engineer and the biologist have already contributed a great share to its solution. There remains, however, no small amount of work for the technical chemist to perform before the desired end is reached.

In an address on 'Chemical Problems of To-day,' delivered by Victor Meyer in 1889, the author pointed out that, although the synthesis of starch from carbon dioxide and water was a result not to be expected in the near future, yet, he says, 'we may reasonably hope that chemistry will teach us to make the fiber of wood the source of human food.' While we do not consider that this is a problem of technical chemistry for the present, the possible use of cellulose as a raw material from which to make food renders more acute a problem which is to-day clamoring for solution, namely, the preservation of our forests. The influence which the forests of a country have upon its civilization is a topic which has been much discussed of late. That there is an intimate relation between the woodland of a district and the regularity of its rainfall, the absence of floods and freshets and the general climatic conditions, there seems now to be little doubt. But the consumption of forest products continues to increase far out of proportion to the growth of new timber. The substitution of other raw material in chemical industries which now use wood for this purpose becomes therefore an economic problem for the solution of which the chemist is held responsible.

The production of cellulose from raw materials other than wood is the first important factor in the chemical side of the question. The weight of wood consumed for the production of chemical fiber for the year 1902 was something over two million tons, while one and a half million tons were used for the manufacture of ground wood pulp. While from some points of view our American forests are sufficient to supply the demand for many years to come, it does not excuse us for the terrible waste of cellulose in forms other than wood which we are constantly suffering.

On our flax fields of the west we are annually burning thousands of tons of flax straw which contains a large percentage of cellulose in a most valuable form. Considerable work has already been done on the utilization of this straw in the production of fiber and some success has met the efforts of the By-Products Paper Company now located at Niagara Falls. There is, however, still much room for improve-

ments. In the straw of our wheat and oats crops, which is to-day largely destroyed on the fields, we have another source of cellulose of which we avail ourselves but little. In Europe the production of straw fiber is carried on to some extent, but is capable of great extension should sufficient economy in the process for treating it be introduced. The high content of silica has ever been a source of loss, owing to the fact that the formation of sodium silicate prevents the recovery of the soda now used in the digestion of the straw.

By far the greatest loss of valuable cellulose, however, is found in waste cornstalks and in bagasse, or in the sugar-cane after the soluble portions have been removed. There is a close analogy between these two products in that there is associated with the woody portion carrying the cellulose a large amount of non-usable pith. Rapid progress has been made in the utilization of both of these raw materials within the last few years, and the indications are that before long they will prove a source of value rather than a nuisance as is frequently the case at present. The market price of bleached cellulose fiber is to-day from two and a half to three and a half cents per pound. Starch may be bought for from two and a half to four cents, according to its source. It is seen, therefore, that there is little manufacturing margin in the conversion of cellulose into starch or sugar until the cost of the former has been considerably reduced. This can come about only through new processes designed to operate more economically than those at present in use and to use as raw products the cellulose at present wasted on the fields.

It would seem that a more economical step towards the production of food from wood might be through its ligneous or non-cellulose constituents. For every ton of cellulose produced there must be used two tons of wood; that is, an equal weight is wasted. In the soda process as now conducted these non-cellulose materials are burned to recover the soda which is held in combination with them. In the sulphite process this enormous amount of material, aggregating for America alone in a single year almost one million tons, finds its way into the water courses and ultimately to the ocean. This organic matter is most complex in its composition, but consists largely of one class of substances closely allied to the sugars, and another class having the general characteristics of tannins. That these sugar like substances could be made to yield a food material is from their nature quite possible; so far as we know, however, but little has been accomplished in this direction. A number of uses have from time to time been proposed for this waste, but as yet none has been of practical value. Among the more promising may be mentioned a *preparation* to be used in tanning leather, a sizing material for paper and a substitute for dextrine in calico printing and as an adhesive.

In addition to our annual supply of 4,000,000 tons of paper stock, we depend upon the forests for our supply of acetic acid, methyl alcohol and acetone. In countries where there is not the exorbitant tax upon fermented mash that exists in the United States there would seem to be an opening for a process for the production of acetic acid from alcohol in a more concentrated form than can be produced through the aid of *mycoderma aceti*. It would, it is true, in the end depend upon the supply of fermentative material; but there are being wasted every year in the semi-tropical countries many thousand tons of crude molasses that could thus serve an economic end. For many uses acetic acid may be displaced by formic acid, a compound which admits of synthesis from carbon and water. The farther this substitution is carried the more acetic acid will be available for the manufacture of acetone and other compounds where the acetyl group is a necessity.

Concurrent with the disappearing forests is the increasing scarcity of vegetable tanning material. Hemlock and oak bark, sumac and chestnut wood are still the most important sources of tannins, although quebracho from South America and canaigre from Mexico and Texas are daily playing a more important part. The introduction of chrome tannage for upper leathers had a marked influence upon this industry inasmuch as it furnished a cheap substitute for those finer tanning materials which were constantly increasing in price. A mineral tannage for heavy hides, along the lines so successfully followed for upper leather has, however, not been developed; the product lacks the rigidity and firmness combined with the flexibility which is characteristic of oak or hemlock tanned leather. There must exist methods for supplying to the hide, materials having an action analogous to these vegetable tannins; it remains but to seek them out in order that a new and profitable industry may be established.

It is thus seen that technical chemistry can do much for the conservation of our forests; along many lines the time for action has already come.

When the consumption of a given article is in excess of its supply the market price must rise. In accordance with this law we have seen the price of crude India rubber more than double in the last few years. The consumer of the finished article must pay this advance or accept an inferior grade of goods. Generally he does both.

The tropical forests of Africa and South America still contain untold quantities of India rubber; but so does sea water contain gold. For manufacturing purposes both might as well not exist. The only human beings that can live under the conditions obtaining in these tropical jungles are the natives; but the distance to which the natives can transport the rubber is comparatively limited. Although rubber-

bearing trees are now being cultivated in the more easily inhabitable portions of the tropics, it will be a long time before this source of supply is an important factor in the market. And thus it comes that the synthesis of india rubber presents to-day, from at least the technical side, one of the most promising problems in chemistry.

The investigation of india rubber is greatly handicapped by the fact that it exists only in the colloidal state. The difficulties are perhaps more largely physical than chemical; that is, it is the molecular aggregation rather than the atomic structure of the individual molecule which presents such almost insurmountable difficulties. There are no clearly defined melting points, boiling points, tendencies to crystallize or any of those means of separating mixtures or characterizing individuals which aid in the investigation of most organic compounds. The researches of Weber and Harris, resulting in the establishment of the much needed methods of analysis, have been of incalculable advantage to all those working with either the raw or the manufactured article. In many directions also the paths along which important results are to be obtained have already been blazed by these investigators. Probably no other field presents such difficulties of manipulation in addition to such profound problems of organic chemistry as does the investigation of india rubber; but on the other hand few such unlimited opportunities for valuable work are offered in the field of chemical research.

Under the general head of utilization of trade wastes may be considered a large number of technical problems the solution of which would not only add wonderfully to the economic resources of the country, but would aid in the solution of that much vexed question, river pollution. We have already mentioned the soda and sulphite liquor resulting from the manufacture of cellulose fiber from wood. Of almost equal importance is the waste yeast which is daily produced in the brewing of beer and ale. An extract of this yeast has a food value as shown by analysis equal to the best meat extracts. As the quantity of yeast allowed to go to waste is from one to two pounds for every barrel of beer brewed, we can form estimates of the great amount of this material at hand. Arsenic sulphide from the purification of crude acids, grease from the washing of wool, the utilization of city garbage and many other problems of this order are everywhere in evidence. It is not within the compass of this discussion to mention these almost innumerable sources of manufacturing waste which exist in the chemical industry; but keen competition on the one hand and the state boards of health on the other are constant stimuli to increased effort towards their utilization.

Although I have endeavored to select the above examples of unsolved problems with a view to touching upon as large a portion of

the field of technical chemistry as possible, I could doubtless with equal propriety have selected others. We can simply mention such important questions as the hygienic preservation of food, the flame-proofing and preservation of wood, prevention of the corrosion of structural iron and steel, the great problems of chemical metallurgy, et cetera. We must, however, note some of the more recently developed forces and phenomena of nature, the application of which to technical chemistry forms problems for to-day. One of the most important of these is electricity. Thanks to the triumphs of modern electrical engineering we are now able to call to our aid unlimited amounts of this agent at a cost comparable to that of other forms of energy. Possibly the simplest, though not the earliest, method of utilizing electrical energy in chemical processes is in supplying the heat necessary to carry on a reaction directly at the point where the reaction takes place. In a number of chemical industries, for example, the manufacture of phosphorus, it was previously necessary to produce within thick walled retorts a very high temperature. The result was that a great deal of heat was wasted, the retorts deteriorated very rapidly and the reaction was carried on at a low efficiency. By using an electric furnace for the manufacture of phosphorus these expensive retorts are eliminated. In addition much cheaper raw materials may be used, the process is made continuous and a high efficiency obtained. By the substitution of electrical heating for the closed retorts previously used in the preparation of carbon bisulphide the manufacture of this chemical has been placed upon an entirely new basis. The economy introduced by supplying the heat at the point where the union of carbon and sulphur takes place is clearly indicated by the low price at which this material can now be sold and its enormously increased consumption.

With the ability to obtain temperatures far above that which is possible by the ordinary combustion of fuel there was opened up a new field in synthetic chemistry. Reactions which it was impossible to carry out on a technical scale and others the existence of which was not suspected are now through the application of electrical energy become the bases of large manufacturing enterprises. Calcium carbide, carborundum, artificial graphite and many hitherto unknown alloys are the commercial products of the electric furnace where temperatures in the neighborhood of 3000° C. obtain.

The third and more strictly chemical application of electrical energy is in the use of the current for electrolysis. Faraday long ago determined the laws according to which chemical compounds break up when subjected to the passage of an electric current. It is only in recent years, however, that the cost of electrical energy has made it possible to apply the knowledge thus furnished by this great in-

vestigator. Among the many important advances due to this use of electricity may be mentioned the manufacture of caustic soda and bleaching powder by the electrolysis of brine. The percentage of the world's supply of these two standard articles which is now made by this process is already a formidable figure and constantly increasing. In the electrolytic production of aluminum we have seen an entirely new industry develop until it is now one of magnificent proportions.

What the application of the electricity will do for technical chemistry in the future can be predicted only by estimating the results of the past. In many fields it is practically virgin soil over which only the pioneers have trod, and which is still waiting to be tilled.

Under the name of catalysis or contact action is included the other force that we can mention this afternoon, the usefulness of which the technical chemist is only beginning to appreciate.

These substances which are capable of so wonderfully increasing or decreasing the speed of a reaction without themselves appearing in its final products vary in their nature from such simple ones as metallic platinum or ferric oxide to the most delicately constituted ferments or enzymes. The manufacture of concentrated sulphuric acid by such a process is perhaps the most striking example of the application of this idea, although to be sure the finely divided platinum used at present plays but the rôle which the oxides of nitrogen have done so successfully in the past. The reproduction of photographic negatives by substituting for the action of light on sensitized paper the contact action of certain chemical compounds, is a process worthy of its distinguished discoverer, Professor Ostwald. For this application of the catalysis idea even the most pessimistic must prophesy a great future. Still another phase of this question is found in the hydrolysis of fats by the enzyme found in the seeds of the castor-oil plant. Instead of the application of acid, heat and pressure the same result is obtained at room temperature by the quiet action of this catalytic body. The advantages to be reaped by the development of these phenomena can scarcely be foreseen. Even the wildest dreamer might easily do injustice to the possibilities of this wonderful agent when intelligently used by the technical chemist.

We probably should not invite criticism were we to state that wherever we find a manufacturing establishment based upon chemical processes, there also exist problems in technical chemistry. That one factor which is so apparent that it scarcely needs mentioning, namely, the increase in the yield of processes now in operation, is enough to substantiate this assertion. The paramount question before us is, therefore, how can these problems best be solved. In any answer to this question there are two factors, both of which deeply affect the future growth of chemical industry. The first is the attitude of the

manufacturer towards science and scientific work; the second is the training of the coming chemist.

When, a few years ago, England awakened to the fact that many industries in which she was the pioneer and at one time the leader were in the main passing to other countries, there went up a great cry for 'technical education.' The nature of the industrial stimulus which has borne such magnificent fruit in Germany was not understood. In the minds of many, a panacea for all their difficulties was to be found in the technical education of the working classes. But this is unquestionably a mistake. Until there is a love of science for its own sake and an appreciation of the value of scientific methods among the leaders of chemical industry, the fruits of technical education can not be reaped. Carl Otto Weber, speaking of this move towards a more general scientific education in England, says "Until the nation as a whole recognizes that the prosecution of scientific study as a mere means of money making is a profanation defeating its own end, the history of industrial development in England will afford the same melancholy spectacle in this, as in the last century, technical education notwithstanding."

The time is past when a factory can be run by rule of thumb; when the chemist is looked down upon simply as a testing machine to be kept at a distance and generally mistrusted. It is true that there are many men to-day who pass under the name of chemist who are little more than testing machines; men who possess the ability to do nothing more than the most strictly routine analysis; but such men will never solve the technical problems of the present or any other time. I would not impugn the dignity or intrinsic value of analytical work—it is the corner stone of all chemical investigation. But I would emphasize the fact, for it is a fact, that the manufacturer who employs a so-called chemist, one trained to 'do' coppers or carbons or acids, and who at the same time expects this chemist to improve his process and keep his business in the skirmish line of the industrial battle, must eventually be numbered among the 'not accounted for.'

The second factor in this answer is the training of the coming chemist. What is the reply to that now so oft repeated question, What is the best preparation for a technical chemist? I am personally of the opinion that it is not to be found in the teaching of applied chemistry, as this term is generally understood. This training must provide for something more than simply copying the present—doing as well as others do; we must build for the future. We must provide men who are prepared to solve the unsolved problems. Within the last few months much has been said and written in America about the lack of adequate instruction in technical chemistry in our universities and colleges. It is assumed that American industries based on

chemical processes do not flourish for lack of men trained in this branch of science. This, however, is not the case. It is not more instruction in applied chemistry that America needs, but rather a deeper and broader knowledge of pure chemistry, with a more extended training in original research.

In many of the problems we have already noticed, the solution depends upon the discovery of new compounds—the investigation and study of new reactions and relationships. This is the province of pure organic and inorganic chemistry. The foundations of these two departments can not be too firmly or too broadly laid. The method of attack best followed in each can not be too well understood. But it is not sufficient that we study only the initial and the final products. It is all important to learn the influence of the variable factors on the process; to study the reaction for itself. This is the province of physical chemistry, a department of science the importance of which to technical chemistry can not be overestimated. To be able to actually apply the laws of chemistry and to predict the course of reactions from general principles already proven is a tremendous economy of both time and energy.

After we have acquired the tools, however, we must learn to use them; after we possess a sound knowledge of inorganic, organic and physical chemistry, we must have adequate training in work requiring original and independent thought.

As I have already noted, the training to be derived from an investigation may be the same even though the incentive for its undertaking may be different. While I believe that so far as possible the student should be influenced to work for the love of knowledge and for the mastery of science for itself, yet especially in his later years of study there are advantages in allowing him to combine with this a utilitarian aim. In America at least most men enter our technical schools with the intention of fitting themselves as rapidly as possible for some useful calling in life. They have a feverish desire to get through and to enter the creative industries and accomplish something. They will work with enthusiasm upon whatever they can be made to recognize as contributing to this end, but by their very directness are intolerant of supposed digressions from their chosen path. The presence of too much of this spirit is to be regretted; but it is a power to be turned to service, not to be opposed. It does not follow that for a training in scientific method and for broadening the mental horizon a research which can have little if any practical value is superior to one the solution of which can find immediate application. For advanced work as much pure organic chemistry, for example, can be learned from an attempt to convert safrol into eugenol (a consummation in itself devoutly to be wished) as in the transformation of

some other compound with a much longer name but with no higher destiny than to fill a place in Beilstein.

So also in physical chemistry. A careful, painstaking investigation of some of our already established industrial processes with a view to determining the maximum yield at the minimum cost is of the greatest educational value. In other words, a problem for research may have a distinctly practical bearing without being any the less a study in pure science, or without having thereby an inferior educational value.

In other problems we have noted, the solution largely depends upon the process, not the reaction. This demands the chemical engineer, a man who combines a broad knowledge of general chemistry with the essentials of mechanical engineering. He must be well schooled in the economics of chemistry; have a knowledge of the strength and chemical resistance of materials; be able to design and operate the mechanical means for carrying out on a commercial scale the reactions discovered, and duplicating the conditions already determined.

With men whose foundations are thus broadly and deeply laid, anxious to enter the industrial arena, and with a generous appreciation of the scientific man on the part of the manufacturer, coupled with a willingness to grant him an adequate return on the money invested in such an education, the problems in technical chemistry of the present must rapidly become the achievements of the past.

# STAMINA.*

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ANALYSIS of vital statistics for the last three-quarters of a century shows an average increase in the duration of human life among civilized peoples from 42.2 years to 48.5 years. The chief increase has been during the latter half of that period, and, for the most part, by the reduced mortality from zymotic diseases, but, above all, from pulmonary tuberculosis, from which the reduction of mortality has been nearly fifty per cent.

Inquiry with regard to the means by which this reduction has been effected, shows it to have been almost wholly by sanitary efforts; by dealing with and destroying unsanitary surroundings, soil-drainage, purifying water supplies, reporting and restricting communicable diseases, sanitary supervision of schools, the destruction of sputum—the now everywhere recognized fountain-head from which the army of bacilli is perpetually reinforced—abolishment of cellar-dwellings, diminished overcrowding, cleanliness, disinfection, isolation and aeration; improved tenements, opened-up and wider streets, public parks and recreation grounds and establishment of sanitaria. This catalogue of sanitary efforts might be still further extended, though altogether without record of special effort for improved nutrition except for nursing infants.

Communicable as all competent observers know tuberculosis to be, while they equally well know that it is not so under all circumstances, it is indeed questionable whether any one of sound constitution and well nourished has ever contracted the disease from nursing consumptives, or from living with them otherwise, under good hygienic surroundings.

On the contrary, no matter how healthful the surroundings or the salubrity of the atmosphere, for poorly nourished and feeble persons, from whatever cause, there is no immunity from tuberculosis. For no one who even approximately comprehends the universality of microbic life—and of none more than tubercle bacilli—can fail to perceive that, however much we may be able to modify the external relations bearing upon liability to tuberculosis, nevertheless every indi-

* Read at the International Congress on Tuberculosis, St. Louis, Mo., October 3, 1904.

vidual, no matter where his dwelling place, is more or less subject to tubercle bacilli; for, besides the utmost restriction of their prevalence by sanitary effort, unless the individual is possessed by an organism sufficiently fortified to resist and overcome conflict with them—for the conflict is certain everywhere—he is liable to contract tuberculosis. Hence it is that about one quarter of all the deaths recorded of mankind during adult life, is caused by tuberculosis, and nearly one half of the entire population, at some time in life, acquires the disease.

Tubercle bacilli are, indeed, abroad everywhere, a constant menace and challenge to one's power of resistance. Every intelligent person knows that the power of resisting the ordinary exciting causes of illness, such as sudden changes of temperature, exposure to damp soil, room or sheets, or night air with the windows closed, depends upon one's state of health. The power of resisting tubercle bacilli is no exception.

Health fortified by such conditions as the organism depends upon for its fabrication and maintenance opposes itself to all exciting causes of disease by the relative integrity, strength and vigor of all the organs and functions of the body. A person thus equipped, if beset by tubercle bacilli or other microbes, effectually resists them, devours them by oxidation and casts them off.

Feebleness, on the contrary, though not always appreciated, and sometimes cultivated, indeed, by the practise of that altogether too popular fad, abstemiousness, is always and everywhere a prevailing 'predisposition' to disease; and, associated as it commonly is with inadequate nourishment, it is the most frequent of all incitants to tuberculosis. Abstemiousness, however, is variable in its practise, and uncertain; one may over-eat and yet abstain from some essential food necessary for the maintenance of health. Adequate nourishment and stamina depend upon the supply of nutriment in the kinds and proportions required by our bodies. Food is required for a two-fold purpose; (1) to supply material for the construction and repair of tissue, and (2) to supply fuel for its maintenance, the production of heat and energy.

It is not necessary to our present purpose to pursue the subject of the origin and nature of food in its general sense, but to emphasize the importance of the essential elements of food comprehended in the various organic and inorganic compounds of which food consists, as follows: Carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, chlorin, iodin, potassium, calcium, magnesium, sodium and iron.

It is not by any means necessary that a food should yield all these elements, indeed there is but one such food—milk—that is complete in this respect, and perfect, upon which the young of all mammalian animals are, or should be, for a time exclusively nourished. Neither

is it essential next following the period of nursing, that every food should be broken up, or 'refined' to facilitate its assimmilation and combinations in the structures of the body, since the functions of the organism are adapted to these processes.

Unfortunately for the infant, however, it frequently happens that after weaning, and if it has been nursed by a healthy mother, or other wet nurse, being well fed on two or three pints of wholesome milk, daily, its food supply is reduced by substitution of one kind or another, more or less devoid of essential elements, with the common result of emaciation and tenderness, and increased liability to sickness. Moreover, as said by Dr. William H. Maxwell, Superintendent of Public Schools of New York City and president of the National Educational Association, in his address at the International Congress of Arts and Science, September 23, 1904:

> Education, whether physical or mental, is seriously retarded, if not practically impossible, when the body is improperly or imperfectly nourished. The child of poverty, with body emaciated, blood thin and nerves on edge, because he has not enough to eat, grows up stunted in body and in mind.
>
> What a farce it is to talk of schools providing equal opportunities for all when there are hundreds of thousands of children in our city schools who can not learn because they are always hungry!
>
> The schools of Paris provide a simple, wholesome midday meal for their hungry children. In many places in the British Islands the same thing is being done. Should we do less in the cities of democratic America? In no other way can we be sure that the schools will, as far as education may, provide equal opportunities for all.

With regard to certain infectious diseases to which children are especially liable, in part, doubtless, because of their greater functional activity, but chiefly because their power of resistance has not yet become sufficiently fortified—for it is well known that adults generally who have not encountered those diseases in childhood rarely contract them subsequently—the same relative immunity exists; the strong and vigorous child is much less likely to contract them than the feeble; and the convalescent, those who are particularly feeble from any one of such diseases, are well known to be the most of all liable to attack and to succumb from another. And of pulmonary consumption, the most prevalent and the most fatal of all diseases, who does not know that enfeeblement invites it? That individuals are less and less liable to it—whether traceable to hereditary taint or otherwise—in proportion as coddling has been avoided, appetite for wholesome fat food cultivated, cold bathing habitual, protective but loose clothing worn, and exercise in the open air unrestrained? By the maintenance of these conditions all the processes of healthy organization are promoted and the constitution fortified against tubercle bacilli, as, in like manner, against other disease germs, no matter whence the quarter or at

whatever the age of the individual exposed; and no less against diseases not attributable to germs—and the more if we accept Metschnikoff's theory of the office of the *leucocytes* or white blood corpuscles, for these in both number and strength depend upon proper nourishment. 'In health,' says Kirke, 'the proportion of white to red corpuscles, which, taking an average, is about 1 to 500 or 600, varies considerably, even in the course of the same day. The variations appear to depend chiefly on the amount and probably also on the kind of food taken, the number of leucocytes being very considerably increased by a meal, and diminished again on fasting. Also in young persons, during pregnancy, and after great loss of blood, there is a large proportion of colorless blood corpuscles, which probably shows that they are more rapidly formed under these circumstances. In old age, on the other hand, their proportion is diminished.'*

No good observer will fail to recognize the coincidence of the condition which diminishes the proportion of leucocytes and the increased liability to disease—that of fasting; or note the no less remarkable coincidence, the diminution in the number of leucocytes and increasing infirmity of old age.

Foods are ordinarily divided into four classes: (1) Nitrogenous or albuminous substances; (2) fats or hydrocarbons; (3) carbohydrates, chiefly starchy substances and sugar; (4) mineral substances—water and salts.

The average daily amount of food required and of the different kinds, as comprehended in this classification, severally, varies considerably with individual conditions of age, size, exercise, circulation, activity of the eliminating organs, etc. The range in different male adults is from 34 to 46 ounces of so-called solid food, and from 70 to 90 ounces of water in some form, taken with and without solid food. For adult females, the average is from 3 to 5 ounces less. For children and youths, proportionally, more in the inverse ratio to age, 0.8 to 0.6 ounces for each pound weight of the body.

If individuals are undergoing great exertion they require more food, and, if they can obtain it, the needful increase is especially in the nitrogenous and fat foods.

Every structure in the body in which any form of energy is manifested (heat, mechanical motion, chemical or electric action, etc.) is nitrogenous. The nerves, the muscles, the gland-cells, the floating cells in the various liquids, the semen, and the ovarian cells, are all nitrogenous. Even the non-cellular liquids passing out into the alimentary canal at various points, which have so great an action in preparing the food in different ways, are not only nitrogenous, but the constancy of this implies the necessity of the nitrogen in order that these actions shall be performed; and the same constancy of the presence of nitrogen, where function is performed, is apparently traceable through the whole world. Surely such constancy proves necessity. (Parkes.)

* Kirke's 'Hand-Book of Physiology,' Vol. I., p. 79.

The average daily quantity of fat required by an adult to keep up healthy nutrition, according to various estimates, is two ounces, and proportionally more during the period of growth, after weaning—from half an ounce to two ounces.

1. A supply of fat, *per se*, to the blood is essential for histogenesis and for the protection of the tissues, and is also of importance for general use as a source of heat and mechanical force.

2. The carbo-hydrates and albuminoids may supply heat and mechanical force, but they can not take the place of fat in histogenesis and protection of tissue.

3. Fats may be supplied by absorption into the portal system, by absorption into the general lymphatic system, and by absorption into the lacteal system. But the latter is the means by which the principal supply of solid fat is carried into the blood, and is the most important.

4. The mean consumption of oxygen by an adult man of average stature (weight, 150 lbs.), taking ordinary exercise, is about thirty ounces in the twenty-four hours, and the heat evolved by each ounce of oxygen in combining with carbon, hydrogen, etc., is about 350 British units. Hence, 10,000 British units of heat will be evolved every twenty-four hours by the combination of thirty ounces of oxygen with carbon, hydrogen, etc.; therefore, the food of an ordinary adult man under ordinary circumstances, should be such as may, in addition to other purposes, evolve at least 10,000 British units of heat.

5. Practical experience in the dieting of large numbers of men, and other means, have enabled us to establish the fact that such an average man as I have spoken of requires for the maintenance of health, a diet which shall contain about four ounces of plastic material, three ounces of fat and ten ounces of carbohydrates; and, on careful analysis of this diet, we find that it can supply the required 10,000 British units of heat, viz., 2,516 from the plastic, 3,357 from the fat and 4,150 from the carbohydrates, total, 10,023.*

Fat, as an article of diet, furnishes the potential force necessary for the conversion of other food material into organic tissue and to maintain the bodily functions.

Professor W. O. Atwater, in one of his most important contributions to the Department of Agriculture,† on the nutritive value of foods, in comparing nutrients in respect to their fuel values, their capacities for yielding heat and mechanical power, states that 'a pound of protein lean meat or albumen of egg is just about equivalent to a pound of sugar or starch, and a little over two pounds of either would be required to equal one pound of the fat of meat or butter.'

The mistake commonly made with reference to the use of fat food is, that it is only, or especially, applicable to cold climates—an erroneous inference, the same as that cold is preventive of tuberculosis. That fat is the almost exclusive food in Arctic regions is because other food is not obtainable, not because of the frigid climate. It is necessary food, though not in such excess, at all times and every-

* 'Loss of Weight, Blood-spitting and Lung Diseases,' Horace Dobell, M.D.

† Farmer's Bulletin, No. 23, 1894.

where, to supply the potential energy required by the organism to construct the tissues and maintain the body, the temperature of the body being about the same in all climates. Fat does not stand alone in this regard, except under such extraordinary circumstances as those referred to. Carbohydrates of various kinds contribute to the same functions as fat, under ordinary conditions, but they do not suffice to maintain the stamina of the organism to the highest degree anywhere without the assistance of, or being supplemented by, some kind of fat.

A correct appreciation of the benefit of fat food in the Arctic regions serves as an index to its advantages under other conditions. It is not limited to blubber, 'toodnoo' or oil, even among the Laplanders. It includes the solid portions of reindeer, seal and other meat. And this in its composition doubtless compares favorably with the choicest cuts of beef and mutton, which consist of 20 to 30 per cent. of fat; or possibly with good bacon or ham, 35 to 50 per cent. Good butter, it need hardly be said, is almost wholly fat—85 to 90 per cent.

Of approximate stamina and exemption from tuberculosis, it is not far fetched to refer to the history of most of the North American Indians, before the cultivation of cereals was introduced by the white settlers. Their food was almost exclusively the fat game which they hunted and killed in such a manner as to retain the blood. Of the wonderful physical strength and endurance of those savages, their history of them furnishes many examples. And the earliest records of consumption among them are contemporary with the attempted methods of civilizing them—inducing them to leave their tents and live in houses; restricting their game supply and supplying them with an excess of farinaceous food. They have ceased to be a hardy race and tuberculosis is common among them. The Gauchos of the South American pampas, who live almost exclusively upon fat animal food, are alike remarkable for their extraordinary stamina. The flesh-eating Mahometans of India are described by historians as being the most powerful, active-minded and hardy race of human beings in the world, presenting the widest possible contrast in physical development to the rice-eating and feeble Hindoos, of whom but few reach the age of forty years.

A striking example of what appears to be the result of a change from an almost exclusive fat meat diet to one largely farinaceous, in relation with tuberculosis, is afforded by the history of the New Zealanders, who, until about fifty years ago, were cannibals, eating their captives in war, but who besides consumed an enormous amount of fat pork. Dogs also composed a part of their dietary, and fish to some extent. They were remarkable for their physical development and exemption from tubercular diseases. But soon after the introduction of the potato as a staple food, at about the time mentioned,

scrofula and other forms of tuberculosis began to prevail among them, and have attained a degree of prevalence even greater than among the poorest people in Ireland, where the staple food is of the same kind, but beneficially supplemented to a considerable extent by the use of buttermilk.

Moreover, I have observed among people in the tropics, as well as in temperate latitudes, that there is a marked difference in the health of persons whose chief food is farinaceous, between those who but rarely eat anything else and are particularly feeble, lymphatic and scrofulous, and those who eat butter or oil with their rice and similar food, or supplement it with sardines in oil, or oil-dressed salads.

Recurring to what I have remarked on the superiority of meat that retain the blood as well as the fat, every epicure knows, and every physician ought to know, that the meat of animals of every kind so killed as to retain the blood is more delicious than that of animals otherwise killed. It is also more digestible and more nutritious. All fresh meat is more or less acid, and that from which the blood has been drained requires to be kept until alkalinity is induced by incipient decomposition before it becomes tender and digestible. On the contrary, that which retains the blood only requires thorough cooling before it is ready for cooking and is tender and digestible from the outset, because the alkalinity of the blood speedily acts upon and neutralizes the acid. Hence, the meat of the buffalo, as it used to be killed and prepared by the North American Indians; the jerked beef of the Gauchos; the beef of cattle that have been knocked in the head, or preferably, by dividing the spinal marrow in the neck, as now practised in the abattoirs of Chicago (if it is not afterward drained of its blood), is greatly superior to that which is prepared after the method of the Jews. Besides, the draining or soaking away of the blood from meat impairs its nutritive value. The blood is essentially of the same composition as the flesh, but besides, it holds in solution phosphates of soda, salts of potash, iron and sulphates; all nutritives of vital importance to the human economy. But there is no method of slaughtering animals that entirely divests the flesh of blood, hence to attempt to prohibit eating it, to be effective, should prohibit the eating of meat altogether.

Relative exemption from tuberculosis, under all circumstances, is, according to my observation, due to the generous use and potentiality of fat food. My conclusion in this regard is fortified by many years' observation and study of the liability to consumption of people collectively, families and individuals, more or less proportional to their abstinence from fat foods. The most prominent example, of which I have never lost sight from youth up, is the negro race in America. I began my professional life among them when they were slaves and

were always supplied with an abundance of 'hog and hominy,' not by any means restricted to these articles, but pork or bacon was a standing portion of at least one daily meal. Consumption among them was relatively rare. My observation in this respect was not singular, but accords with all other medical observers of the time, of whom I have knowledge. Conversely, it seems hardly necessary to invite attention to the prevalence of consumption among the same people now, under their changed conditions with regard to diet. 'Hog' at least is notable by its absence from the daily fare of most of them and no other fat meat has taken its place; and consumption among them is more than twice as great as it was formerly.

The same observation extends to smaller communities, families and individuals. Consumption is most prevalent among those who are stinted or who stint themselves of 'bacon' and 'butter.' I mention these as ideal and because they are among the most digestible of fat foods; other fat foods are commendable. Everybody has learned, when it is unfortunately, in most cases, too late, that cod-liver oil is good for consumptives, but few seem to have learned that food of the same character as cod-liver oil, suitable for the table, is preventive of consumption.

In the whole course of my professional observation, now covering a period of more than sixty years, I have never known a family or an individual that was brought up on a liberal supply of butter and bacon who became tuberculous. Moreover, such food fortifies the system against other diseases as well as consumption; it establishes stamina.

# THE NATURAL HISTORY OF ADOLESCENCE.*

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THE history of philosophical thought itself participates in the scheme of evolutionary progress which it expounds and records. The sequence of culture changes and the soil of motives in which these find root remain the permanently vital sources by which to illustrate and to comprehend the nature of human endowment, striving and achievement. For only half a century have we had access to an adequate point of view that brings into the vista of the progress of the ages the nature and the scope of evolutionary forces. This added insight has come, more than any single factor, to stamp the pattern of modern thought. We look backward not only with a different equipment in the way of telescopic aids to such retrospective vision, but with very different anticipation of what is thus to be discovered, and of its significance.

Though the application of evolutionary principles to mental endowment has kept pace with its advance within the more strictly biological field; and though the factors which psychological processes have themselves contributed to the trend of evolution have been of late prominently recognized, yet the sum-total of these recognitions has gone rather toward adding some chapters and an appendix or two to the volume of philosophy, than towards the rewriting of the whole. Yet the latter type of reconstruction of philosophy and psychology is by no means unrepresented. The manner of such representation naturally varies with author and subject, with scope and purpose; but it is possible to set down a score or more of titles indicative of the absorption into the ripest psychological thought of the tissue of evolutionary doctrine. In some aspects this tendency appears in a still more intensive and comprehensive form than has yet been accorded it, in the psychological work of large dimensions which President G. Stanley Hall has recently brought to an issue. The dominant message of his pages is the notable one that psychology must ever remain close to biology; that considerations of origin and of the potent past must ever illuminate the road to the future.

* 'Adolescence, its Psychology and its Relations to Physiology, Anthropology, Sociology, Sex, Crime Religion and Education,' by G. Stanley Hall, Ph.D., LL.D., president of Clark University and professor of psychology and pedagogy. D. Appleton and Company, New York, 1905. Two volumes. Pp. 589 + 784.

The central topic about which this doctrine is elaborated is that of adolescence—that specialized, reconstructive period fraught with the highest possibilities and the severest risks for the future of the individual, and representing nature's point of emphasis in the perspective of human and racial development. The volumes accordingly constitute in the first place an encyclopedia of adolescence. They bring together with a degree of completeness quite unattempted hitherto, the main data concerning the natural history of this period of unfoldment, on its physical, physiological and psychological sides. The normal growth of the body, the special development of different portions thereof concerned with adolescence, the variations from such normal development and their aberrations in disease and crime, the great rôle that periodicity plays in human growth—these constitute the physical basis which conditions through and through the nature of mental growth, as well as determines the spirit of educational progressions. The considerable aggregate of special studies that have been made in all parts of this wide field are here carefully summarized; so that as a book of reference the work takes a commanding position. There will be a variety of opinion as to the specific and permanent value of much of this evidence; and there may be some who will call into question the validity of the question-sheet system by which much of the psychological portion of the material has been gathered. Yet those who weigh evidence in a fair spirit of criticism will find that on the whole the weakness of certain types of evidence, for which unfortunately we have no better substitute, is quite as clearly recognized by the author as by themselves. It is easy enough to discredit the results obtained by a somewhat miscellaneous set of answers to questions, many of them rather difficult to answer with conscience and pertinence. But here, as everywhere in statistical investigation, all depends upon the temper and discretion that are used in the interpretation of the results. If the method used for the extraction of the result is adapted to the nature of the material, then it is likely that the investigation, however deficient, has served a useful purpose. It is not necessary to defend the *questionnaire* system in itself or the use which Dr. Hall and his pupils have made of it; the real point of issue is how far such material will stand the strain of the conclusions which are based thereupon. Allowing for a wide divergence of opinion in this respect, there remains a very considerable body of evidence which is tangible and well classified, and in the aggregate has a significance in that it suggests the trend of emphasis of the growth and distribution of mental traits. It is difficult, indeed, to understand by what other means an equally adequate conception of the contents, the impulses and the modes of feeling of young minds could have been ascertained, or the larger conclusions involved therein more saliently suggested. Nor must it be supposed that Dr. Hall has limited himself to this form of evidence.

Quite apart from the more physical investigations, where statistical methods yield more concrete and definite results, he has utilized direct experimentation where that has been possible, has cited the larger records of history, of literature, and of the more technical portions of psychology and biology. It must forever remain true that advance in this field of comparative psychology must make use of arguments by analogy, of parallelisms, assisted by direct reinforcement of evidence from the investigations of animal life, from the study of the abnormal, from the lessons of history. Method here is not a matter of theoretical preference, but of judgment; and the ability that can turn method into account, not subordinating the chief end to its requirements nor distorting method to strengthen favorite conclusions, is the equipment which the investigator in this field must possess to an unusual degree. Appreciating the difficulties of this undertaking, students of psychology and education, unless they believe that Dr. Hall is fundamentally following a false clue, have reason to be deeply grateful for so much of this work as constitutes an encyclopedia of adolescence. They have the privilege, which many will doubtless exercise, of discrediting this or that group of data; but they can hardly help recognizing that the general perspective of importance and bearing based upon the material thus made available, has on the whole been ably reproduced.

The chapters that best represent this encyclopedic feature are those that deal (the first two) with the varied and detailed factors of physical changes of growth; the fourth, which deals with the disorders of immaturity; the ninth, that treats of changes in the sense endowment and in the voice; and again the later chapters, recounting from a more historical point of view the recognition of adolescence in custom (Chapter XIII.), in religion (Chapter XIV.), in society (Chapter XV.), together with the racial problem of adolescence, which must be treated both theoretically and practically whenever higher races come in contact with lower ones (Chapter XVIII.). A second group of chapters takes up more specifically those questions that are central to adolescence, and in which the element of sex predominates. Chapters VI. and VII. consider the more physiological portions of this problem; Chapter XI. is devoted to adolescent love; while Chapter XVII. contains a *résumé* of the entire topic of the feminine side of adolescence in psychology and education. A third group of chapters includes those in which the philosophic basis is uppermost and which together constitutes in some measure a statement of the author's philosophical and psychological point of view. Chapter X., on evolution and the feelings and instincts characteristic of normal adolescence; Chapter XVI.; on intellectual development and education; Chapter VIII., which considers adolescence in literature, biography and history, represent the more distinctively philosophical contributions; while Chapter III., on the development of the motor powers, represents the

best illustration of the combination of all three interests as applied to a single topic.

The selection of this third group of topics for more especial notice is the natural one, as therein are contained the points of view that have directed the entire work as it became formulated in the author's mind, and upon the value of which its ultimate standing will depend. What is known as the 'recapitulation theory' becomes in Dr. Hall's treatment a direct aid to interpretation as well as a guide to interest and application. Its central message is fairly familiar, and emphasizes the fact that there is contained in our physical and functional heredity the vestiges of the several slow and tortuous changes that have intervened between the earliest forms of life and their successive unfoldment into that diversified series of organisms culminating in *homo sapiens*. The doctrine thus means that the oldest of human structural traits and functional tendencies must find their analogy, as well as their type of explanation, in a study of animal and of primitive human characteristics.

Like many a biological trait, and most typically like the great fact of sex itself, this principle has a wide range of secondary implications. Among these the accounting for present human traits, by means of those strongest in primitive life, of the type that we find among uncultured peoples, is of all the most comprehensive. It gives to that longer and more fundamental life of human endeavor a living participation in the make-up of present psychic traits, and prevents an overestimation of the importance of those newer and less inwardly absorbed tendencies which we too exclusively regard as coming within the ken of psychology, and too exclusively train in systems of education. More concretely, this principle emphasizes the importance, for the comprehension and the training of minds, of the life of the feelings and of the will. Men have felt and men have acted for ages before they guided their actions by thought; and the reverberation of these long emotionally ruled periods must have left decided traces upon those tendencies which will best be expressed in the early and adolescent stages of the individual. The history of philosophic opinion itself in interpreted by Dr. Hall in terms of a similar development, in which immature adolescent systems, staid senescent and *blasé* philosophies have appeared and appealed to their public in direct relation to the status of the culture-periods in which they found origin and favor. Our own day is decidedly that of the exaggeration of the rational processes, of complete subordination of feelings and will to thought. This type of cerebration is as evident in the studies that we teach, in the education that we favor, as in the philosophies that we read. With the last, indeed, Dr. Hall has a special issue; regarding, as he does, that this indulgence in speculation of the theory-of-knowledge type, has tended to inject unduly into psychological considerations the spirit and the

interest of metaphysicians. The explanation in philosophical terms of thought and reality has usurped, in his opinion, the larger, more fruitful as well as more hopeful interest in the functional manifestations of the deeper, more universal and significant aspects of mind.

An analagous emphasis must be placed upon action as opposed to thought. The study of motor impulses becomes as fundamental in psychology, and motor training as fundamental in education, as any analysis of how we think, or any teachable wisdom in the guidance of thought. The motor response is as vital to the psychological mode of manifestation as the ability to defend policy by argument or to analyze results into processes. In all these several aspects the position of woman has remained closer and truer to nature than that of man. And to this, the specific trait of feminine psychology, Dr. Hall traces her peculiar distribution and emphasis of brain, heart and hand—a distribution that represents an older, more typical as well as more natural set of relations. The educational application of these several principles lies close at hand. Indeed, to some readers the volumes, as a whole, will appeal more strongly on their practical side as a guide to education than on their analytic side as a guide to a perspective of importance of the several contributory factors of modern psychology. These educational applications are stated with considerable elaboration, at times with distinct and exaggerated oratorical appeal, and as frequently with suggestive and earnest reformatory programs. No one of these practise-guiding principles is more convincingly dealt with than that which leads to the appeal for the proper representation in the educational scheme, of the training of the hand and the will. The dignity and rights of motor education receive an unusually strong and comprehensive recognition. And here as elsewhere, we are reminded in general and in detail that the order of control over muscles and the apparatus of the will is indicated by its natural growth in the child and in the race. The value of the discovery of the natural order in this as in other series of evolutions is that the natural order is the right order; that our efforts should go to encourage for the several periods the conditions and stimuli that nature provides, to avoid at least the most serious of the antagonisms to that sequence of growth, which the needs of civilization (or our imperfect means of preparing for them) seem to demand.

The crowning application of these several precepts and practices is to those special phases of growth which find their joint issue in adolescence. Here more than anywhere else must the natural sequence of evolution determine the variety of occupation that shall prepare for the adult life; and here too, according to Dr. Hall, have our transgressions against the order of nature been most serious. We have imposed upon the adolescent endowment the interests of mature individuals, have invited them to share our adult consciousness, not even taking care

to adapt the methods of assimilation to the apperceptive appetite of the young. And the extreme instance of such misapplication is in the efforts of those who attempt to assimilate the education of women to that of men, and who take as their model the type of masculine education against which these strictures most especially apply. Not that the author is arguing against the higher education of women or even specifically against all forms of coeducation, but that he makes a plea both for young men and for young women, for that form of education, and for such favorable conditions of growth, as correspond in both cases most nearly to their individual and very different needs. Thus psychology—properly interpreted as the study of the evolution of mental functions—at once appraises the value of mental traits, and in recovering the trade-routes of the past, points to the most profitable highways of the future. Psychology of this type and temper remains the supreme guide of education. The discussion as to what benefit this or that teacher, or teachers as a whole, may derive from the study of psychology is not prominently considered; yet the affirmative attitude towards the problem is implied. But particularly are we asked to discountenance as of slight profit, or even as pernicious, that type of psychologizing that remains unrelated to the vital functions of life, 'If truth is edification, the highest criterion of pure science is its educative value.'

With this estimate of the nature and purpose of psychological inquiry, Dr. Hall attacks with an almost bewildering variety of equipment the entrenched position of adolescence. This is central, the key to the situation, because the maturing of mind and body which then takes place represents the key-stone of the arch which up to then has been building. It indicates that the stages of mental growth anticipating adolescence form a separate and formative type of psychological study; that a knowledge of the changes which then take place is as vital a matter of human concern as can well be imagined; and that the shaping of interest, which then first buds, remains the supreme question of educational practice. Thus both for education and for psychology, adolescence has a directive importance. The weakness, alike of education and of psychology is, in Dr. Hall's opinion, largely due to the comparative neglect of those interests that the study of adolescence discovers and illuminates. Education and psychology are in danger of becoming scholastic because they are fashioned too much in the study and by the book, and reflect too little knowledge of the world and of the byways as well as of the highways of life. It is, after all, but a small part of psychology that can profitably concern itself with how the mental processes of the adult consciousness can best be presented and explained. A far more vital and comprehensive problem is the comprehension of how men and women, and particularly boys and girls, feel and act as well as think. The study of impulse and motives, not merely of such as lie in a direct line or cultural advance, but equally

those that suggest the abnormal, that which when magnified becomes disease, and most of all that which harks back and suggests the psychic mode of action of our primitive ancestors, merit chief consideration; such, apart from the specific applications to the physical and mental hygiene of adolescence, are the conclusions and argument that have guided the author in years of labor, compilation and record.

The effect of so comprehensive and many sided a work as this inevitably depends in no small measure upon the manner of its presentation. This is uneven in the several chapters and rises to the point of complete satisfaction in few. To many the style will be distinctly unattractive, as it suggests a somewhat Teutonic attempt to carry more luggage than the journey warrants. Some will find it a loss to their special purposes to have the special presentation of facts so closely interwoven with the enunciation of principles. More will object to the cumbersome sentences, elaborated paragraphs and detailed summaries. It must be confessed that these frequently suggest the mode of progress of the burdened stage-coach rather than the directness of the pony-express. But as some traverse the ground with the interest of prospective settlers, and others with that of tourists only, it would be difficult in any event to satisfy both needs. Yet in this respect the work falls short of that pedagogical effectiveness upon which the author himself lays emphasis. Indeed, he must not be surprised to find the charge which he makes against other systems of philosophy, namely, that they open large vistas, but that the view enjoyed therefrom is distant and hazy, will be applied against himself. Yet one must hasten to record that the practical issues are nowhere lost sight of, though the path followed in bringing them to light is often needlessly detailed and circuitous.

That equal exception will be taken alike to the main positions of the work and to the detailed applications therein is not unexpected. Dr. Hall distinctly appreciates the imperfection of his own efforts; but these efforts represent the convictions of as long a stretch of teaching and of as close study of a wide range of data, as is the case with any representative of his craft. In a more distinctive way than any other student of mind in America, Dr. Hall has canvassed the field both on its practical and theoretical sides, and has bided his time for many years, eventually placing on record this issue of his encyclopedic labor, his varied experience, his wide observation of men and things. Quite irrespective of the degree to which his views will find ready acceptance among his colleagues and the public at large, the importance of the problems discussed and the originality contributed to their discussions, as well as the encyclopedic comprehension of what is thus put together, make these volumes a distinctly notable achievement in the field of psychology and education.

The objective account thus rendered of the comprehensive under-

taking serves the purpose of indicating its contents, its arguments and the trend of its conclusions. Such an account is inevitably incomplete, but suffers a conspicuous incompleteness if it refrains wholly from any expressly critical estimate of the value and probable influence of the more original and distinctive doctrines for which the work stands. In regard to methods and the kind of criticism which they invite and will doubtless receive, enough has been said. The most pertinent inquiry pertains to the attitude which close students of psychology and of education are likely to assume towards the main positions of the author, and—equally important—the impression which the views thus first formally recorded are likely to make upon the considerable circle of interested and intelligent laymen. In this connection it is not of paramount importance that one should speak exactly for himself, legitimate as that would be; it is equally pertinent to set forth as well as may in him lie, the attitude of those who share with him many of his interests and his general perspective. Approaching the matter with this purpose, one notices a larger representation on the opposition benches than in those set aside for the government supporters. The case of the opposition will be strong and carry a fair measure of conviction; the argument will be advanced, that while the principles thus advanced carry some measure of support from biology, the use to which said principles are put far transcends the warrant of the evidence, and in certain of the deductions seems indeed in contradiction to it. The biological status of recapitulation leaves no such definite provision, not even in the earliest stages of infancy, for such complex appearance of prehuman traits as Dr. Hall advances. To explain the impulse of children when in the presence of water to jump in and swim, as a reverberation of an aquatic habit, seems both feeble and inconclusive. The case becomes stronger and at the same time changes its aspect, when traits favored by primitive human life are brought into operation to account for the vast medley of impulses and feelings which in great part we have shared and then outgrown. Yet even here the transfer from the one field to the other seems better justified when limited to general groups of traits than when literally translated into the deciphering of the variable and complex as well as evanescent characters of changing juvenility. In other words, many who will admit a limited applicability of the general parallelism would hesitate to stand sponsor for the special application and practical deductions that seem the goal of so many of the Clark University studies in this field. Nor is it going too far to add that Dr. Hall's educational insight has a firmer hold upon his pen than his logical adherence to the recapitulation theory. His educational precepts impress one as finding their inspiration in a broad and discerning observation, intermittently reinforced by an elaborated conformity to the principle which at times becomes only imperfectly germane to the plan and the spirit of the

exposition. In brief, psychologists are rather likely, with a reasonable variation of cordiality, to endorse the emphasis which Dr. Hall's studies have led him to place upon certain aspects of mental evolution, but rather unlikely to endorse his special and insistent applications thereof. Likewise will they hesitate to join forces with him in his subservience of so many other normative trends in psychology to the dominance of the evolutionary and atavistic influences from which in his accounts so many human blessings and their opposites flow.

It has already been indicated that psychologists and laymen alike will find their sense of obligation to those volumes lessened by certain peculiarities of presentation that seem to result from a too ardent desire for judiciously modified and at the same time richly comprehensive statements. This detraction from the possible influence of the work is more serious for the layman; and it is to be feared that these volumes, extensive and difficult to read, will lose a considerable measure of the influence which the interest of the subject would have, under more favorable circumstances, commanded. Equally must it be said that the extreme, and to many minds needlessly urgent, frankness in the treatment of topics usually (even if we admit at times unwisely) debarred from public consideration, will give offense in quarters where a less drastic treatment would have saved the situation without sacrificing the pedagogical effect. That this element in the work has already led to the exclusion of the volume from certain public libraries can easily be ascertained. Those who read between the lines will acquire a conviction of greater sympathy with the author than with his book. They may come to feel, what those who are acquainted with the author's career know, that his influence in shaping psychological and educational interests is sounder and more effective and distinctly more suggestive than his recorded position. These mixed feelings of attraction and repulsion, together with the strain of orientation of thought already referred to, will further diminish the influence of the volumes among the lay public. This criticism may be fairly interpreted to mean that the author has attempted too complex and many-sided a task, rather than that he has in any sense failed to accomplish the purpose which he set before him. It may well be that two different books, each addressed to a separate set of readers, would have diminished the sense of lack of fitness to their special needs which the layman and the psychologist—to say nothing of the student of education—now feel.

Having thus indicated the characteristics of the volumes which are likely to detract from the more general acceptance of the positions taken therein and from a proper appreciation of the work among lay readers, it remains only to repeat the estimate more objectively stated above, that the comprehensiveness of the task and the ability of the author will in the end, and in more directions than have here been indicated, gain for the work a distinct recognition as one of the notable contributions of American scholarship to the field of psychology.

# HIGHER EDUCATION OF WOMEN AND RACE SUICIDE.

By A. LAPTHORN SMITH, B.A., M.D.
MONTREAL.

EDUCATION on the continent of America, and more especially in the United States, has reached a point of perfection which hardly leaves room for any further development.* At first sight, this would seem to be a very satisfactory state of affairs and, to the ordinary observer, the question of still higher education would seem to be deserving of all praise. 'You can not have too much of a good thing,' they say, and the very highest possible degree of education for women is none too good or too great for them. But to those who look beyond the present and only a little way into the future a great danger is gradually arising, a danger which will go on increasing until it brings about a revolution the signs of which are already beginning to be seen and which will effectually put an end to the evil which is to form the subject of this paper. The author will limit himself principally to a discussion of the harm resulting from too high an education of women, because on that part of the subject he has had exceptional opportunities for observation and for drawing accurate conclusions; but, incidentally, he will take the liberty of questioning the advisability of affording *higher* education freely to the people at large, of the male, as well as of the female sex.

The author regrets to be like a voice crying in the wilderness, a note of warning against what the majority of people consider to be an unalloyed blessing; and some will no doubt say that he is going back to the time of the great preacher who said 'he that increaseth knowledge increaseth sorrow.' And yet all the facts on which his conclusions are based are known to many thousands, and even millions, of people in America, and even, though to a lesser extent, in England, where the same disastrous results are following the same apparently innocent cause. The author would crave the indulgence of his readers, if, at times, he is obliged to speak of delicate matters in rather a plain way; but where this has to be done he will endeavor to do it in such a manner as not to offend the sensibilities of any scientific reader.

In the human race, as among every species throughout creation, as every well-informed person knows, there is constantly going on

* The American boy is generally admitted to be the *smartest* on earth, while the American girl is still more clever and brilliant than her brother.

a struggle for existence—not only for the existence of the particular individual, but for that of his progeny, which is of far greater importance in nature, because when the individual is wiped out, only one person disappears; but when his progeny ceases to exist, an end is put to countless thousands, who are thus prevented from ever being born. He will endeavor to show, as he believes to be the case, that the higher education of women is surely extinguishing her race, both directly by its effects on her organization, and, indirectly, by rendering early marriage impossible for the average man.

First of all, is education being carried on at present to such a degree as to at all affect the bodily or physical health of women? This is a very important question, because the duties of wifehood, and still more of motherhood, do not require an extraordinary development of the brain, but they must absolutely have a strong development of the body. Not only does wifehood and motherhood not require an extraordinary development of the brain, but the latter is a decided barrier against the proper performance of these duties. Any family physician could give innumerable cases out of his experience of failures of marriage, directly due to too great a cultivation of the female intellect, which results in the scorning to perform those duties which are cheerfully performed, and even desired, by the uneducated wife. The duties of motherhood are direct rivals of brain work, for they both require for their performance an exclusive and plentiful supply of phosphates. These are obtained from the food in greater or less quantity, but rarely, if ever, in sufficient quantity to supply an active and highly educated intellect, and, at the same time, the wants of the growing child. The latter before birth must extract from its mother's blood all the chemical salts necessary for the formation of its bony skeleton and for other tissues; and in this rivalry between the offspring and the intellect how often has not the family physician seen the brain lose in the struggle. The mother's reason totters and falls, in some cases to such an extent as to require her removal to an insane asylum; while in others, she only regains her reason after the prolonged administration of phosphates, to make up for the loss entailed by the growth of the child. Sometimes, however, it is the child which suffers, and it is born defectively nourished or rickety, and, owing to the poor quality of the mother's milk, it obtains a precarious existence from artificial foods, which at the best are a poor substitute for nature's nourishment. The highly educated woman seems to know that she will make a poor mother, for she marries rarely and late and, when she does, the number of children is very small. The argument is sometimes used that it is better to have only one child and bring it up with extraordinary care than to have six or eight children brought up with ordinary care because in

the latter case the mother's attention is divided. But this is a fallacy. Everybody knows that the one child of the wealthy and highly educated couple is generally a spoiled child and has as a rule, poor health; while the six or eight children of the poor and moderately educated woman are exceedingly strong and lusty. But even supposing that the highly educated woman were able and willing to bear and rear her children like any other woman, she has one drawback from having a fairly large family, and that is the lateness at which she marries, the average being between twenty-six and twenty-seven years. Now, as a woman of that age should marry a man between ten and fifteen years older than herself, for a woman of twenty-seven is as old as a man of forty for the purpose of marriage, both she and her husband are too old to begin the raising of an ordinary sized family. Men and women of that age are old maids and old bachelors. They have been living their own lives during their best years; they have become set in their ways, they must have their own pleasures; in a word, they have become selfish. And, after having had one or at the most two children, the woman objects to having any more, and this is the beginning of the end of marital happiness. The records of our divorce courts show in hundreds of instances, that there was no trouble in the home while the woman was performing her functions of motherhood, but that trouble began as soon as she began to shirk them. Hundreds of thousands of men at the present day are married, but have no wives; and while this sad state of affairs occurs occasionally among the moderately educated, it exists very frequently among the highly educated.

Is the health of the women at the present day worse than it was in the time of our grandmothers? Are the duties of wifehood and motherhood really harder to perform now than they were one hundred years ago? Without hesitation the answer to both questions is 'Yes.' Not only are the sexual and maternal instincts of the average woman becoming less and less from year to year; the best proof of which is later and later marriages and fewer and fewer children; but, in the writer's opinion, the majority of women of the middle and upper classes are sick and suffering before marriage and are physically disabled from performing physiological functions in a natural manner. At a recent meeting of a well-known society of specialists for obstetrics and diseases of women, one of the fellows with the largest practise in the largest city on this continent stated that it was physically impossible for the majority of his patients to have a natural labor, because their power to feel pain was so great, while their muscular power was so little. On these two questions the whole profession is agreed, but I am bound to say that there is a difference of opinion as to the reason. Several of the most distinguished fellows of the above society claim that the generally prevalent breakdown of women is due to their inor-

dinate pursuit of pleasure during the ten years which elapse between their leaving school and their marriage. This includes late hours, turning night into day, insufficient sleep, improper diet, improper clothing and want of exercise. The writer claims that most of the generally admitted poor health of women is due to over education, which first deprives them of sunlight and fresh air for the greater part of their time; second, takes every drop of blood away to the brain from the growing organs of generation; third, develops their nervous system at the expense of all their other systems, muscular, digestive, generative, etc.; fourth, leads them to live an abnormal single life until the age of twenty-six or twenty-seven instead of being married at eighteen, which is the latest that nature meant them to remain single; fifth, raises their requirements so high that they can not marry a young man in good health.

There is another aspect of the question, which is not often discussed, but which has an important bearing upon it. The very essence of cultivation of intellect to its highest point consists in raising the standard of one's requirements. A contented mind makes a man happy. Does a high education make one's mind contented, or does it make it discontented with the present, and ever struggle towards a higher ideal in the future? Is the woman who is versed in art and literature contented with a simple home, or must she be surrounded with objects of art and more or less costly books; and, if so, is she satisfied with her lot when she marries an average man, who is able to provide for her all the necessaries of life, but is not possessed of sufficient wealth to provide those things which would be useless luxuries to a woman of ordinary education, but which are necessities for her? Not only must the highly educated woman have an artistic home, large enough to hold her artistic and literary collections, and roomy enough in which to entertain her artistic friends, but she must have a certain number of expensive and highly trained assistants, to keep these large collections in proper order. In plain language, she must have servants to clean them and move them about without destroying them. Can such a woman, anxious and worried over the care of several thousands or hundreds of objects of art, devote the same care to the bearing and bringing up of her family as the woman whose ordinary education has made her feel no need of possessing such objects, but who, on the contrary, is content with a home and furniture which she herself is oftentimes alone capable of taking care of?

We all want to be happy, and to that end we all want to be good; and, I have already said, we want our children, especially our boys, to be good and happy. But those who know anything about virtue in the male know that the marriage of our young men under twenty-

five, to a woman with a sound body about eighteen years of age, is almost, if not the only, means of preserving the virtue of the rising generation of men. People, and even mothers, speak lightly of their daughters at twenty-six or twenty-seven marrying men who have sown their wild oats; but one must reap what he sows and do they realize what an awful misfortune such a harvest has brought to the character of the man, and will almost surely bring to the health of the innocent woman? If one has any doubts on this subject they would soon be set right by the testimony of any physician who has made a specialty of attending men, or who has devoted his practise especially to women.

Just as there are occasionally cases where a divorce becomes necessary, but very much fewer than those actually granted, so, occasionally, the life of an unborn child must be sacrificed to save the life of the mother. But will anybody pretend for a moment that there is any excuse for the two million of child-murders which is a fair estimate of the number occurring annually on the North American continent? The crime has become so general that public opinion has ceased to condemn it, and among the few who do condemn it we certainly do not find those women who claim that wifehood and motherhood are degrading and should be reserved to the lowest class of the population. It is well known that were it not for the enormous immigration pouring into America day by day and week by week, the population of this continent would have died out ere now. And it is generally admitted that the original American people have almost died out. Even the foreigners who are so quickly assimilated soon learn the practise of race-suicide, although never to the appalling extent of the native-born Americans. As far as my experience goes, the crime is most prevalent among the highly educated classes, while it is almost unknown among those with an ordinary education.

Another way in which the higher education is making people unhappy is in the cultivation of the powers of analysis and criticism. When the power of analysis is applied to one's own self it is especially unfortunate, for then it becomes introspection, a faculty which is carried so far with some women that their whole life is spent in looking into themselves, caring nothing for the trials or troubles of those about them. This produces an intense form of egotism and selfishness. These people are exceedingly unhappy, very often suffering from what is wrongly called 'nervous prostration,' but which should rather be called 'nervous prosperity.' When the wonderful power of criticizing is applied to others it takes the form of fault-finding. Such a woman must have many victims; will she make them happy?

One of the greatest objections to the higher education of women, namely, the interference with outdoor exercise, no longer can be raised,

because the universities and boarding-schools have within the last ten years foreseen this danger and met it by special courses of instruction in athletics and the encouraging of girls to spend a good deal of time in outdoor sports. But even these universities and schools cannot avoid the charge of fostering a condition of intellectual pride, which is in exact proportion to the success of the school or college. There is no doubt that women can do everything that men can do, and a great deal more; but the knowledge of their ability brings with it an aggressive, self-assertive, independent character, which renders it impossible to love, honor and obey the men of their social circles who are the brothers of their schoolmates, and who in the effort to become rich enough to afford the luxury of a highly educated wife have to begin young at business or in the factory, and for whom it is impossible to ever place themselves on an intellectual equality with the women whom they should marry. These men are, as a rule, refused by the brilliant college graduate, and are either shipwrecked for life and for eternity by remaining single, or are only saved by marrying a woman who is their social inferior, but who, by reason of her contented mind, in the end makes them a much better helpmate than the fault-finding intellectual woman who is looking for an impossible ideal.

The catholic church has, for many centuries, realized the importance of marriage and maternity in the upbuilding and strengthening of religious life in the community; and if the protestant churches are not to be emptied of their male attendance, the protestant clergy must speak out in no uncertain tone against the present methods of education, which are turning out women by the thousands, with requirements so varied and so great that no young man can afford to marry them; a step, moreover, which he is deterred from taking by the discouraging report of those of his friends who have ventured to marry the women of their own class, and who have advised them, in the words of Punch: 'To those about to marry, don't.' Whether a man should marry or not is too often spoken of lightly and as a joke. But to those who believe in the immortality of the soul, and that the whole world avails nothing to a man if he loses it, the possibility of early and happy marriages becomes a question of the vastest importance and one which students of sociology, and the fathers of the nation should study with the most intense anxiety and care.

Occasionally a college graduate goes through the ordeal* of a high education, which has developed her intellect without ruining either

* The following subjects from the curriculum of a well known girl's college: Latin, Greek, French, German, English, mathematics, physics, chemistry, astronomy, history, sociology, economics, logic, psychology, philosophy, literature, fine arts, biology, physical training, physiology.

her body or her natural instincts; but, as far as the writer can see, she is decidedly an exception. To the average highly intellectual woman the ordinary cares of wifehood and motherhood are exceedingly irksome and distasteful, and the majority of such women unhesitatingly say that they will not marry, unless they can get a man who can afford to keep them in luxury and supply them with their intellectual requirements. The gradual disappearance of the home, which any thoughtful observer must deplore, is, to a large extent, the result of the discontentment of the educated woman with the duties and surroundings of wifehood and motherhood, and the thirst for concerts, theaters, pictures and parties, which keep her in the public gaze, to the loss of her health and the ruin, very often, of her husband's happiness.

Fortunately, nature kills off the woman who shirks motherhood, but, unfortunately, it takes her a generation to do it; and in that short lifetime she is able to make one or many people unhappy.

What about the supply of female school teachers? Is not the very highest education possible necessary for them? From the writer's point of view most of the women who are now teaching school should have been married at eighteen and in a house of their own which might have been the schoolmaster's home. The profession of teaching was once exclusively in the hands of the men, and it can not be denied that they have achieved some great results. But as education rendered an ever-increasing number of women unsuited for marriage, that is, unwilling to marry the available men, they invaded the schoolmaster's rank to such an extent that his salary has been cut down one half, and now he is unable to marry at all. Two well-known consequences have followed this state of affairs; first it is impossible to get men in sufficient numbers to become teachers for the boys' schools; and secondly, even big boys being taught by women, the effeminization of our men is gradually taking place. Although there are some instances of a mother alone having formed her son into a manly man, yet as a rule the boys require the example of a man's character to make them manly men. This subject has recently been dealt with in several elaborate papers by well-known educationalists, to whom it appears to be a real danger to the coming generation.

What about the men? If the higher education prevents the women from being good wives and mothers, will it not prevent the men from being good husbands and fathers? To some extent it does, and in so far it is a misfortune, but to a much less extent than among women, for the simple reason that the man contributes so little towards the new being; while, on the other hand, high intellectual training enables him to win in the struggle for existence much better than if he were possessed of mere brute force. But nature punishes the man

who has all the natural instinct cultivated out of him, just as it does the woman, namely, by the extinction of his race. For the struggle for existence among the highly educated men has become so keen, because there are so many of them, that great numbers of them are unable to earn a living even for themselves; while the supporting of a highly educated woman, with her thousand and one requirements, is simply out of the question. A president of a great company recently informed the writer that he had, in one month, applications from eighty-seven university graduates for a position equivalent to that of an office boy at fifteen dollars a month while out of one hundred millionaires, at least ninety-five of them are known not to have been highly educated; but, on the contrary, to have left school between fourteen and sixteen years of age. So there is such a thing as learning too much, without knowing how to do anything. Just as athletes may be overtrained, so men may be overeducated.

This great question has received the attention of one of the brightest men of our age—no less than the chief magistrate of the United States; while quite recently, in the British House of Lords, the Right Reverend Dr. Boyd-Carpenter, Bishop of Ripon, from his seat in that august assemblage, has called attention to the lateness of the age for marriage and the diminishing birth-rate, foreseeing, no doubt, that these two factors would soon be followed by the emptying of the churches and the lowering of the high standard of British morals and character.

The writer feels certain that, before long, this subject will receive the attention which it deserves from those who love their country and have the forming of its destiny in their hands. If he succeeds, by this or any other means, in drawing their attention to it, he will have fulfilled the object of his paper.

# SIMPLE BACTERIOLOGY FOR PUBLIC SCHOOLS.

By LILLIAN CHAPIN, B. S.,
INSTRUCTOR IN CALUMET HIGH SCHOOL, CHICAGO.

HYGIENE is the one secondary school subject that every pupil will find necessary throughout life. In few high schools, however, has it received the treatment a subject of such importance demands. This article is a plea for definite, forceful experiments and demonstrations in hygiene comparable with the experiments and demonstrations so long deemed essential in physics and chemistry. The following experiments could be done in any secondary school.

1. *To demonstrate Bacteria in the Air.*—A test-tube of sterile nutrient agar was melted by immersing it in boiling water. The agar was then poured into a sterile Petri dish, where it cooled and solidified in a thin film. The cover of the dish was then removed and the medium exposed to the air for ten minutes. The cover was replaced and the dish set aside. Two days later, there had developed on the agar 63 colonies of bacteria. A dish prepared in the same way, but not exposed to the air, developed no colonies.

2. *To demonstrate Bacteria in Water.*—A test-tube of agar was melted and placed in water at 42° C., a temperature slightly above that of the human body. At this temperature, agar remains liquefied, but it is not hot enough to kill bacteria. Two tiny drops of drinking water were transferred to this melted agar by means of a small, sterile loop of platinum wire. The agar was then poured into a sterile Petri dish. A few days later, the dish was found to contain fourteen colonies of bacteria.

3. *To demonstrate Bacteria in Milk.*—In the same way, a test-tube of agar was inoculated with two tiny drops of milk, and the agar poured into a sterile Petri dish. In this dish 192 colonies developed.

4. *To show the Effect of Heat on Bacteria.*—Three test-tubes of milk were taken. The first was kept at room temperature, the second was immersed in water at 60° C., and the third placed in boiling water. At the end of twenty minutes, Petri dishes were prepared from each tube, with the following results:

| | | |
|---|---|---|
| Unheated milk | 192 | colonies. |
| Milk heated to 60° C. | 13 | " |
| Milk heated to 100° C. | 5 | " |

5. *To determine the Effect of Freezing upon Bacteria.*—Two test-tubes of water were used. One was kept at room temperature, the

other was frozen solid by means of a mixture of salt and ice. At the end of twenty minutes the frozen specimen was allowed to melt. Petri dishes were then prepared from each, with the following results:

| | |
|---|---|
| Not frozen | 272 colonies. |
| Frozen | 294 " |

In a similar experiment with milk, 192 colonies developed from the sample kept at room temperature, and 193 colonies from the sample frozen.

6. *To show the Effect of Temperature on the Rate of Multiplication of Bacteria.*—Three test-tubes of milk were used. A Petri dish made from the milk at this time showed 80 colonies of bacteria. The first tube was placed in an ice chest, the second was kept in a locker, and the third was put in an incubator. Petri dishes made from each, twenty-four hours later, showed the following counts:

| | |
|---|---|
| Ice chest (4° C.) | 70 colonies. |
| Locker (20° C.) | 30,000 " |
| Incubator (37° C.) | 100,000 " |

7. *To show the Effect of Drying on Bacteria.*—Three loops full of beef broth in which typhoid fever germs* were growing, were transferred to each of two dry, sterile test-tubes. Into the first tube, melted agar was poured, and then poured out into a sterile Petri dish. The drops in the second test-tube were allowed to dry, and a day or two later a Petri dish was prepared from this tube in the same way. The two Petri dishes showed the following counts:

| | |
|---|---|
| Specimen not dried | 6,000 colonies. |
| Dried specimen | 0 " |

8. *To determine the Effect of Sunlight on Bacteria.*—Two slips of filter paper were wet with a beef-broth culture of typhoid. The papers were placed in sterile test-tubes, which were sealed with paraffine to prevent drying. One of the test-tubes was placed in a locker. The other was exposed to sunlight for three hours. Petri dishes were then prepared, which showed the following counts:

| | |
|---|---|
| Paper not exposed to sunlight | 100,000 colonies. |
| Paper exposed to sunlight | 0 " |

9. *A study of Antiseptics.*—Four test-tubes were prepared, each containing 5 c.c. of water to which typhoid bacilli had been added. To the first tube nothing was added. Half a cubic centimeter of a weak solution of the antiseptic to be tested was added to the second. To the third, 1 c.c., and to the fourth 2 c.c. of the antiseptic. Twenty

* In repeating this experiment in high schools, harmless bacteria must, of course, be used. The colon bacillus is recommended for this purpose.

minutes later Petri dishes were prepared from each tube, with the following results:

| Antiseptic. | 0 c.c. | ½ c.c. | 1 c.c. | 2 c.c. |
|---|---|---|---|---|
| 5 per cent. Carbolic Acid | 446 | 237 | 95 | 20 |
| 95 per cent. Alcohol | 446 | 96 | 25 | 1 |
| Salicylic Acid (Sat. sol.) | 3640 | 298 | 60 | 15 |
| $\frac{1}{10}$ per cent. Mercuric Chloride | 3640 | 3 | 1 | 0 |

10. *To disinfect a Room.*—Three slips of filter paper were moistened with a beef-broth culture of typhoid, and placed in large glass jars. In the first jar sulphur was burned. Into the second jar formaline vapor was passed. The third jar was not treated with a disinfectant. A few hours later, Petri dishes were prepared from each paper. They showed the following counts:

| | |
|---|---|
| No disinfectant | 100,000 colonies. |
| Sulphur fumes | 6 " |
| Formaline vapor | 0 " |

11. *To show the Effect of Food Preservatives on the Rate of Multiplication of Bacteria.*—Two test-tubes, each containing 5 c.c. of fresh milk, were used. A Petri dish made from the milk at this time showed 83 colonies of bacteria. To one of the tubes about two grams of common salt were added. The second tube was not treated. The tubes were kept in a locker over night. Petri dishes were then made from them with the following results:

| | |
|---|---|
| No preservative | 7,520 colonies. |
| Salt | 850 " |

12. *To show the Antiseptic Properties of Gastric Juice.*—An artificial gastric juice was prepared by dissolving a little pepsin in a ¼ per cent. solution of hydrochloric acid. To 1 c.c. of this juice, ¼ c.c. of a beef-broth culture of typhoid bacilli was added, and Petri dishes made from the mixture at intervals for half an hour. The number of colonies developing on these dishes is tabulated below. To get an idea of the number of germs originally added to the gastric juice, the same amount of typhoid culture was added to 1 c.c. of sterile water and a Petri dish prepared from this mixture. The number of colonies on this dish is recorded as the count for 0 minutes.

| | | | |
|---|---|---|---|
| 0 | minutes | 35,200 | colonies. |
| 2 | " | 157 | " |
| 15 | " | 3 | " |
| 30 | " | 0 | " |

13. *To show the Antiseptic Properties of Human Serum.*—Under the supervision of a physician, a small amount of blood was drawn, by means of a hypodermic needle, from a vein in the arm. This blood

was placed in a sterile glass vessel and allowed to clot. After standing some time, serum separated. One cubic centimeter of this serum was placed in a small test-tube and five loops full of a beef-broth culture of typhoid bacilli were added to it. Petri dishes were made from this mixture at intervals for an hour. To get an idea of the number of germs originally placed in the serum, a control was run with 1 c.c. of sterile water. The count made from this control is recorded as the count for 0 minutes.

| | | | |
|---|---|---|---|
| 0 | minutes | 3,760 | colonies. |
| 2 | " | 737 | " |
| 8 | " | 410 | " |
| 15 | " | 34 | " |
| 30 | " | 2 | " |
| 60 | " | 0 | " |

12. *To show that Bacteria are not given off from a Moist Surface.*—A culture of harmless, brilliant yellow bacteria was smeared on the inside of a large glass tube. Through this tube a strong current of air was directed on to agar in a Petri dish. If bacteria were given off into the air from the moist surface, they would be blown upon the agar, where they would develop into colonies. The Petri dish used in this experiment developed no yellow colonies. The smear was now allowed to dry and was then crushed with a sterile glass rod. A second current of air was now directed through the tube into another Petri dish. This dish developed 240 colonies of yellow bacteria.

The above is merely suggestive of the kind of work that might be done in any secondary school. Most of these experiments could be performed by the average high school senior. All of them could be used as class demonstrations. Each one has a direct bearing on some large question of preventive medicine. A week's training in bacteriological technic will enable any teacher to give this work.

The experiments here outlined were suggested to me by Dr. W. H. Manwaring, and were carried out in the Pathological Laboratory of the University of Chicago, during the summer of 1904.

## SHORTER ARTICLES AND CORRESPONDENCE.

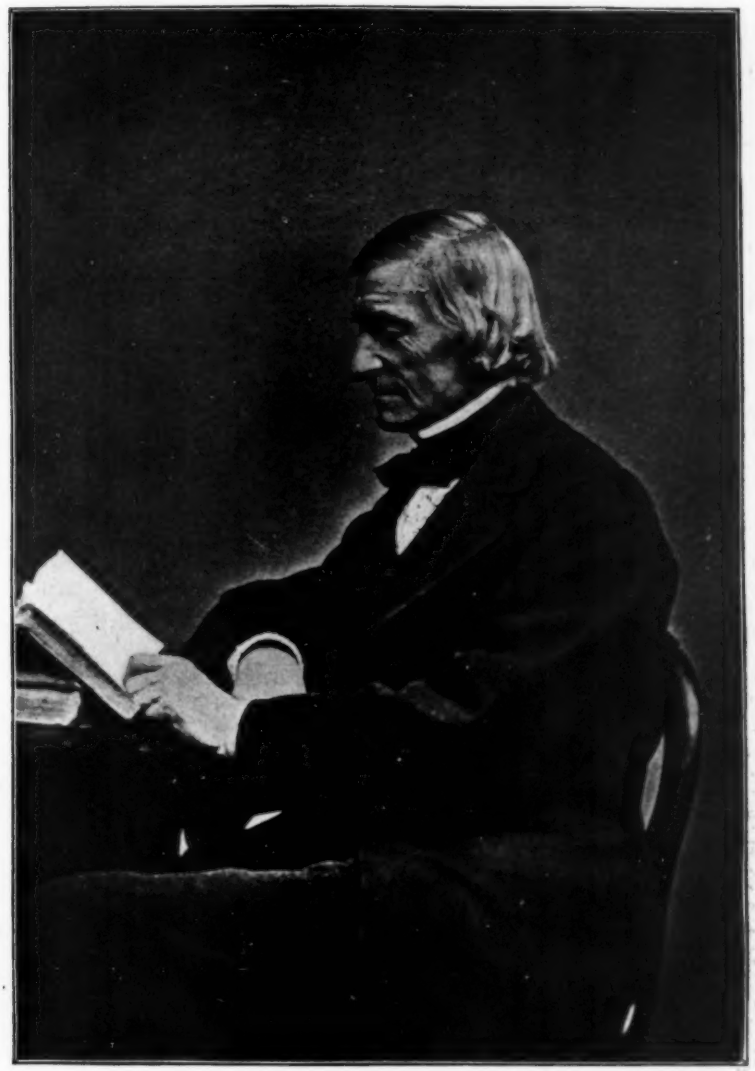
### *THE CENTENNIAL OF WILLIAM BARTON ROGERS.*

On the seventh of December at the Massachusetts Institute of Technology, in a convocation of students and faculty, were held exercises in commemoration of the one hundredth anniversary of the birth of William Barton Rogers, the founder and first president of the institute. These exercises were of more than local interest, because the man in whose honor they were held has filled a great place in American education and American science. Born in Philadalphia in 1804, he passed his early boyhood and manhood at the old William and Mary College at Williamsburg, Va. In this institution his father was professor of natural science, and in the academic freedom of which this college was then one of the few exemplars, the young Rogers was able to follow the leadings of his own genius. He became professor there in 1828, and was transferred to the University of Virginia, in 1835, as professor of natural philosophy. His career in the latter place was one of great influence and power, not only as a teacher, but as an investigator. In connection with his talented brother he inaugurated the geological survey of Virginia, which survey has become almost a classic.

While living here and during frequent trips to Europe he became impressed with the need in America of institutions in which scientific studies might form the basis of education; and his removal to Boston, in 1853, was in large measure due to his belief that in this community was to be found a better opportunity for the founding of such an institution than in Virginia. Nothing which Mr. Rogers did could have more clearly indicated his good judgment than this conclusion, for there was certainly no community in America so ready for the building of a great technical school as Boston.

Here, amidst the stress of the years of the civil war and under all the discouragements which those years brought he founded the Institute of Technology, which forms to-day his greatest monument and which continued to be, until the very close of his life, his chief concern. He died splendidly, in the very act of service, at the Commencement of June, 1882, as he was addressing the graduating class. Combining as he did the charm of a gracious and pleasing personality with the power of an orator, of a great teacher and of an investigator it is not strange that those who have received their education in the Institute of Technology should have for him a reverence and an affection far above that which they entertain for any other man. In the truest and fullest sense the institute was founded by him, and in large measure drew its inspiration and life from his enthusiasm and devotion.

The exercises held on December 7 were simple, but full of tender regard for President Rogers and his work. An introductory address by the president of the institute dealt with a general estimate of the originality and breadth of Mr. Rogers's educational conceptions. President Lyon G. Tyler, of William and Mary College, told of the influence of that famous institution in the forming of Mr. Rogers's character and in the training of his genius. Professor Francis H. Smith, of the University of Virginia, spoke as an old pupil of Mr. Rogers and of his power as a great teacher. Professor Robert H.

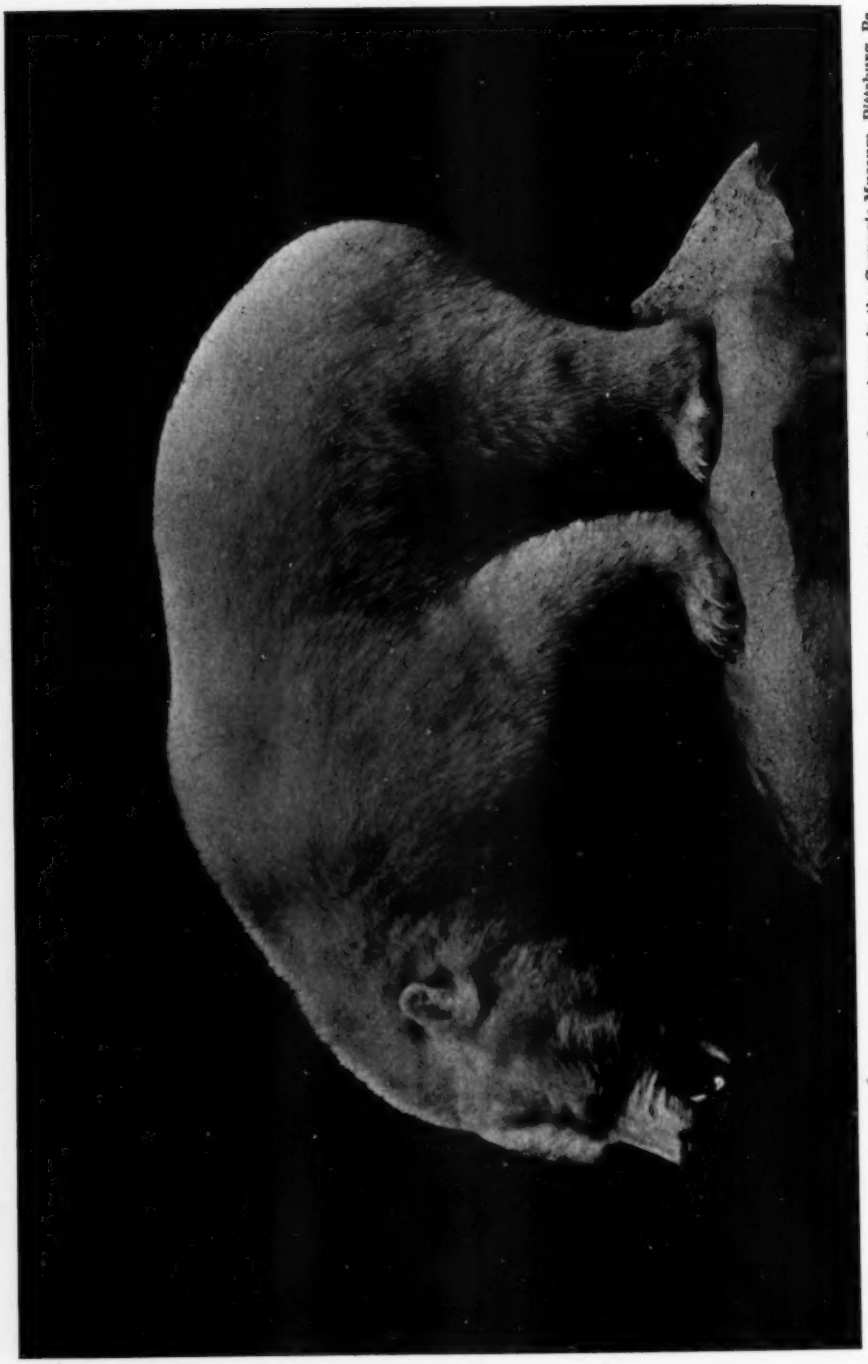


WILLIAM BARTON ROGERS.

Richards, a graduate of the first class of the Institute of Technology, related interesting events connected with the early beginnings of the institute.

At the close of these exercises an announcement was made that the corporation of the institute, out of funds in its control, had founded a scholarship of $300 yearly to be filled by a graduate or student of William and Mary College to be designated by the faculty of that institution. The exercises throughout were such as to impress upon the student body the nobility and loftiness of Mr. Rogers's character and life and to give a new estimate to those who knew him of the permanence and warmth of the memory in which he is yet held.

HENRY S. PRITCHETT.



SIDE VIEW OF THE INLAND WHITE BEAR (*Ursus kermodei* Hornaday). From a photograph of the mounted specimen in the Carnegie Museum, Pittsburg, Pa.

## THE INLAND WHITE BEAR.

A FEW weeks ago the writer had the pleasure of welcoming at the Carnegie Museum his honored friend, Mr. Wm. T. Hornaday, the Director of the Zoological Gardens in Bronx Park, New York. Conversation turned upon the latest discoveries in the field of zoological research, and Mr. Hornaday announced that he had just described a new species of bear, 'The Inland White Bear,' to which he had applied the name of *Ursus kermodei*. After Mr. Hornaday had given the writer the substance of his article, which, as he said, would be read in New York on the evening of the very day we were chatting together, the writer asked him whether he 'would like to see a mounted specimen of the beast.' A look of surprise passed over his features, but in a moment he was piloted to one of the exhibition halls of the Carnegie Museum, and there he saw, what he least expected to see, a beautiful mounted specimen of the animal.

This specimen was acquired by purchase from Mr. Frederic S. Webster, the veteran taxidermist, at the time when his private collection was purchased by the trustees of the Carnegie Institute and he accepted the position of chief preparator in the Section of Zoology in the museum. For many years it has stood in a case and has been pointed out as an 'albino black bear.'

The story of its original acquisition by Mr. Webster may best be told in the words of Mr. Webster himself:

"A number of years ago the firm of Arnold, Constable & Co., of New York, purchased in the London market a lot of skins of the polar bear. I was at that time in business in New York and these skins, a dozen or more of them, were turned over to me to be made up into rugs. In the bundle I found the skin of this little bear, which I at once recognized as not being a Polar bear. I had never seen such a specimen before, but concluded that it was the skin of an albino black bear. I purchased the skin and mounted it. The skull was with the head. The specimen was in excellent condition. The fact that the muzzle was black, and not pale in color, as would be likely to be the case in an albino animal, puzzled me at the time. The thickness of the woolly fur also attracted my attention, but having mounted the animal, I did not give the matter much thought afterward."

The specimen, of which a picture from a photograph by Mr. A. S. Coggeshall is herewith given, is thus far the only mounted specimen known to exist in any of the museums of the world. The skin is no doubt that of an individual taken in British Columbia, the home of the animal, which found its way into the London fur market from Canada. It was mistaken for an immature Polar bear, and was so classified by the dealer who sold the bundle of skins to the agent of Messrs. Arnold, Constable & Co.

W. J. HOLLAND.

CARNEGIE MUSEUM,
February 3, 1905.

# THE PROGRESS OF SCIENCE.

## *THE CARNEGIE INSTITUTION OF WASHINGTON.*

IT is natural that the Carnegie Institution should claim frequent attention in a monthly report on the progress of science. Never before has there been an attempt on so large a scale to stimulate scientific research. The Royal Society of London; the Academies of Sciences of Paris, Berlin, Vienna, St. Petersburg and Rome; The Royal Institution of London, and the Smithsonian Institution, combined, do not have an income approaching that of the Carnegie Institution, nor have they the same freedom in the disposition of their funds. The third year book of the institution, which has just been published, is consequently a document of great interest to all those who concern themselves with the advancement of science. An artificial interest is further given to the annual report because the officers have hitherto followed the policy of not announcing until the end of the year their grants and appointments. An exception was of course made in the case of the president elected at the December meeting of the trustees to succeed Dr. Gilman; and we have already congratulated the institution and the research work of the country on the appointment of Professor R. S. Woodward, of Columbia University, to this important position.

It appears from the financial statement in the year-book that the disbursements for grants last year amounted to $267,232; for publication to $11,590, and for administration to $26,957. A reserve fund is being accumulated, $196,957 having been invested in railway bonds and there being a cash balance of $461,902. Appropriations have, however, been made for the current year that will exceed the income. They are as follows:

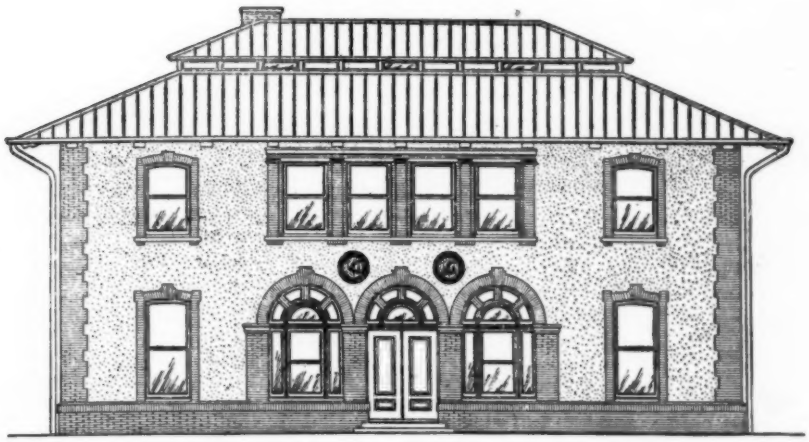
| | |
|---|---|
| Reserve fund | $ 50,000 |
| Publication fund, to be continuously available | 40,000 |
| Administration | 50,000 |
| Grants for departments and large projects | 310,000 |
| Grants for miscellaneous researches | 168,000 |

The most important project undertaken by the institution last year was the establishment of a department of experimental biology. Dr. Charles B. Davenport, of the University of Chicago, was appointed director of a Station for Experimental Evolution at Cold Spring Harbor, Long Island, and

SEAL OF THE CARNEGIE INSTITUTION.

Dr. Alfred G. Mayer, of the Brooklyn Institute of Arts and Science, was appointed director of a Marine Biological Laboratory at the Dry Tortugas, Florida. A grant of $34,250 was made to the station at Cold Spring Harbor, and of $20,000 to the laboratory at the Dry Tortugas.

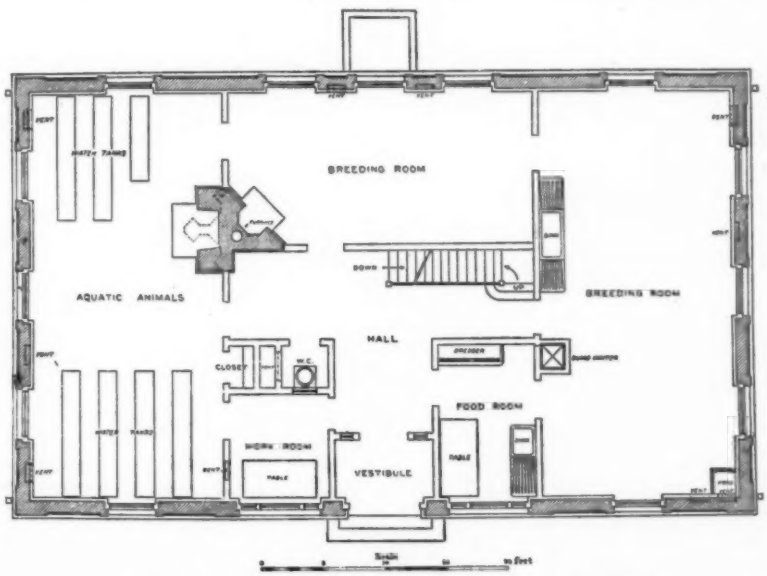
We reproduce illustrations showing the buildings of these laboratories and the yacht built for the southern station. A grant of $40,000 was made for tropical Pacific exploration, but it seems that Mr. Agassiz preferred to



STATION FOR EXPERIMENTAL EVOLUTION AT COLD SPRING HARBOR.

undertake the expedition without accepting the grant.

The other large projects are research in geophysics, in charge of Dr. George F. Becker ($25,000); a department of terrestrial magnetism, in charge of Dr. L. A. Bauer ($20,000); a Trans-Caspian archeological expedition, under Dr. Raphael Pumpelly ($18,000); a department of economics and sociology, under President Carroll D. Wright ($30,000), and a bureau of historical research, under Professor A. C. McLaughlin ($8,500). In the secondary grants, astronomy appears to have been favored. Professor George E. Hale received three grants aggregating $22,000, and, according to the daily papers, he has this year received a grant of $150,000 for a solar observatory on Mount Wilson. The next largest grants in astronomy were




SECOND FLOOR PLAN OF THE COLD SPRING HARBOR STATION.

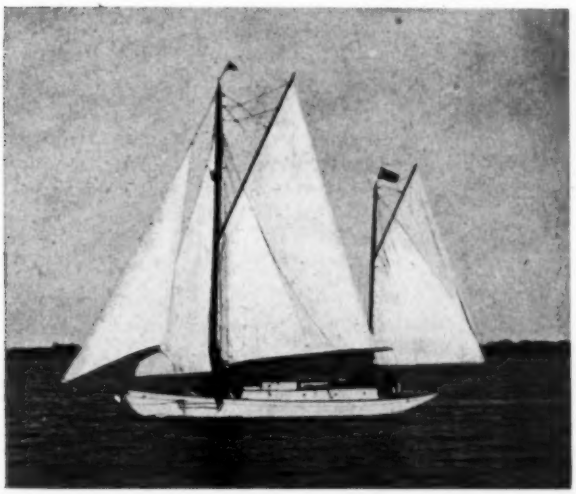
$5,000 to Dr. Lewis Boss, Dudley Observatory, Albany, N. Y., for astronomical observations and computations, and $4,000 to Professor W. W. Campbell for pay of assistants in researches at Lick Observatory.

Several of the largest appropriations were made in bibliography: $10,000 to Dr. Robert Fletcher, Army Medical Museum, Washington, D.C., for preparing and publishing the Index Medicus; $7,500 to Ewald Flügel, Stanford University, for the preparation of a lexicon to the works of Chaucer, and $5,000 to Mr. Herbert Putnam, Washington, D. C., for preparing and publishing a handbook of learned societies.

Other grants as large as $5,000 were for the desert botanical laboratory, described by Professor Lloyd in the last issue of the MONTHLY, $5,000; to Bailey Willis, U. S. Geological Survey, Washington, for geological exploration in eastern China, $12,000; for the Marine Biological Laboratory, at Woods Hole, Mass., $10,000; to Professor W. F. M. Goss, Purdue University, for a research to determine the value of high steam pressures in locomotive service, $5,000; to Professor W. O. Atwater, Wesleyan University, for investigations in nutrition, $7,000; to Professor Arthur Gamgee, Montreux, Switzerland, for preparing a report on the physiology of nutrition, $6,500. Numerous smaller grants were made from $100 upwards, and twenty-five research assistants were appointed with stipends ranging from $1,000 to $1,800.

It is perhaps too early to express an opinion on the fruitfulness of the work of the institution. It appears that the large projects are more likely to yield valuable results than the smaller grants. The department of experimental evolution is certainly a useful undertaking, though we should prefer to see a laboratory established and left to develop as a separate institution on its own lines. The same is true of the solar observatory on Mount Wilson. Admirable work is sure to be accomplished under Professor Hale's direction, and an observatory should be established where the 'seeing' is the best. But the Yerkes Observatory was recently built and equipped with the largest of telescopes, and it seems unfortunate that it should be necessary for the director and part of the staff to be transferred at the expense of the Carnegie Institution to a new observatory in California, where there is already a mountain observatory of world-wide reputation. In most, though not in all, cases the secondary grants appear to have been safely bestowed, but usually for rather obvious and routine work, which might pro-

THE MARINE BIOLOGICAL LABORATORY AT TORTUGAS, FLORIDA.



THE PHYSALIA, THE YACHT OF THE FLORIDA STATION.

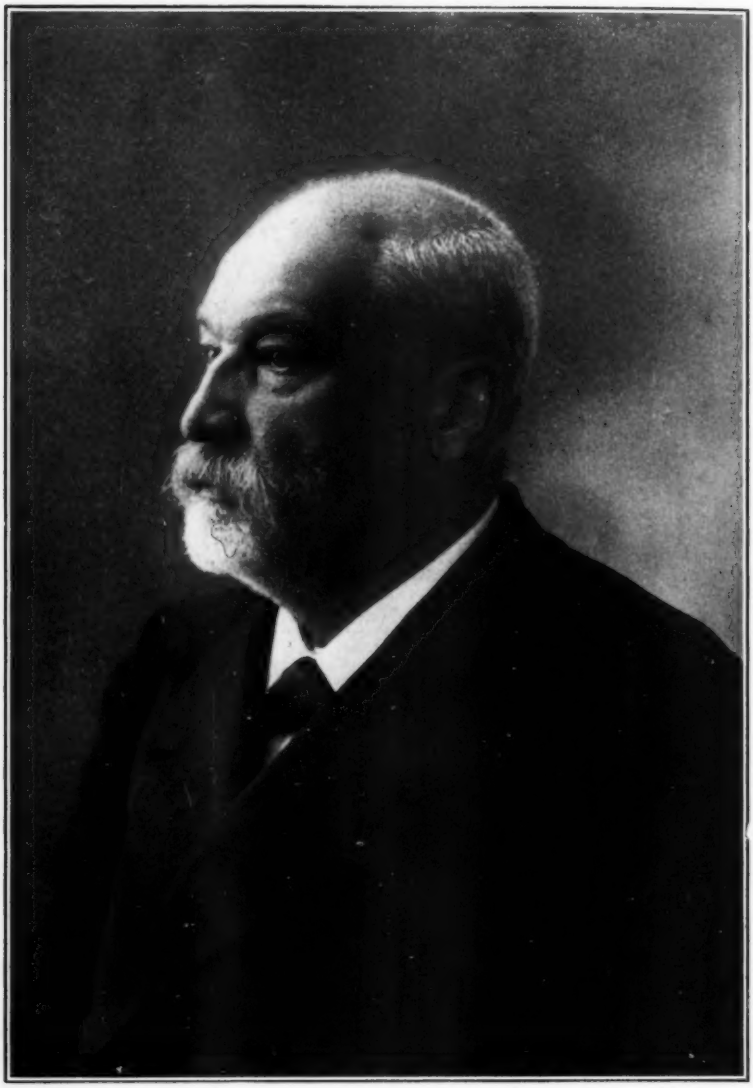
ceed nearly as rapidly without them. Money so expended is certainly not wasted, but it is doubtful whether it is used to the best advantage. We must acknowledge that in America we do not so much lack money and equipment as men who will devote themselves unreservedly to scholarship and research. How money can be used to produce and assist such men is a problem yet to be solved.

## *CLEMENS ALEXANDER WINKLER.*

WHILE Germany has called a third chemist from outside the boundaries of the empire supposed to contain the greatest chemists of the world, the death of this truly great and truly German chemist must be doubly felt, and the earnest words of warning repeatedly uttered by him should make a new and lasting impression; for surely something must be amiss in the boasted perfection of German chemistry when Germany finds it necessary to call on Russia, Holland and Sweden to find chemists for the chairs in her greatest universities. A remarkable critical article—the last one written by Clemens Winkler—was printed in the January number of THE POPULAR SCIENCE MONTHLY; it forcibly presents the judgment of the discoverer of germanium on one of the dominant phases of chemical investigation of the present day, in which again German chemists are seen to occupy an extreme position, though they in this field also are merely followers, not originators. Since American chemists are wont to follow their, largely German, teachers, this critical paper deserves special attention in this country.

Clemens Winkler seemed predestined for chemistry. His ancestors for many generations were identified with the mining and smelting industries of old Freiberg; his father, Kurt Winkler, was especially prominent in this chemical industry and had been greatly favored as one of the last foreign students admitted to the private laboratory of Berzelius at Stockholm. The perfection of the analytical work of Clemens Winkler may be traced to this origin, which he himself was proud to remember, and which may also account for the fact, that some of his most critical analytical work was first published in the transactions of the Swedish Academy of Sciences.

Another favorable condition influencing Winkler's career was the fact that two of the most prominent men



CLEMENS ALEXANDER WINKLER.

of science of the Freiberg Mining Academy were his uncles, namely the great engineer, Julius Weisbach, and the renowned mineralogist, August Breithaupt. The greatest practical achievements of Winkler combine those two fields of investigation, namely, the manufacture of sulphuric acid by the contact method, from the waste gases of roasting ores, and the rapid and accurate analysis of furnace gases. His treatise on volumetric analysis is also specially excellent in its methods of reduction. Both these works have passed through three editions; his contact method was awarded a grand prize at the St. Louis World's Fair.

The discovery of the element germanium, by which Winkler has been known best throughout the chemical

world, also bears the mark of highest skill in both chemical and mineralogical sciences; for this element was detected in a very rare and always very thin coating of a silver ore occurring in but very few localities. Notwithstanding the exceeding scantness of the material, Winkler established the chemical character of the new element solidly by a complete study of its compounds and the production of the real element in the free state. Some of his original samples of this noted work could be seen in the German Chemical Exhibition at St. Louis this summer.

Clemens Winkler was born at Freiberg, Saxony, December 26, 1838; he became professor of chemistry there in 1873, and continued in this work with great success till his health failed in 1902, when he removed to Dresden, where he died after great suffering on October 8, 1904.

### *GREEK AT THE ENGLISH UNIVERSITIES.*

THE ancient English universities are just now much concerned over the tide of modern culture that is surging about their borders. Oxford has voted to sit Canute-like, while at Cambridge the decision is yet to be made. The question has passed beyond the limits of the universities and is being actively discussed in the newspapers and magazines. The proposal that was rejected by a small majority at Oxford was to exempt from the entrance examination in Greek candidates for honors in mathematics and natural science, while at Cambridge the syndicate has recommended making Greek optional in the 'little go.' The teachers at Cambridge would probably vote for the change, but the question must be decided by convocation, the masters of arts who consist largely of country clergymen. There is no doubt as to the ultimate outcome, as the medical men and others having a scientific education will soon be more numerous than those who take orders. It should indeed be remembered that the English universities are, on the whole, less conservative in this direction than our own, for while they demand a classical school education for entrance, they do not require any study of Latin or Greek at the university for the degree of bachelor of arts.

In America we are concerned with the decision of Oxford, owing to the Rhodes scholars, who are now passing their first year of residence there. At the examination of the College Entrance Examination Board last year the largest number taking a paper in Greek was 176, whereas there were 351 in physics, 661 in French, 693 in German, 1,033 in English and 1,060 in mathematics. The selection of Rhodes scholars must be made from that one sixth of the students entering college who have studied Greek, unless the language is crammed for the examination. Of the representatives of the forty-three states now at Oxford, sixteen have entered for languages, thirteen for law and only three for science.

While the discrimination in favor of the classical languages and against the sciences at Oxford and to a lesser extent at Cambridge can not be approved by a scientific journal, and will probably be abolished in the near future, something may be urged in its favor. There is too great a tendency for our universities to lose individuality by making them places where everybody can learn anything. The newer English universities, such as London, Liverpool and Birmingham, are largely schools of science, and it might be wise to maintain one university based on classical learning. A home of lost causes and impossible loyalties exerts a certain commanding fascination over those who are subdued to its influence. From a wider point of view, there is something provincial in the attitude of a man such as Professor Jebb, who looks with contempt on the New Zealanders, because they are supposed to speak of 'Cupid and Sich,' while he himself is doubtless completely ignorant of the socialistic movement among

that people which in the future history of the world will exert an influence out of comparison with the pretty fables of antiquity. But in the widening current of democracy and the broader fields of modern culture room is left for those who cling to the classical traditions, and there seems to be no reason to desecrate their particular shrine.

## *SCIENTIFIC ITEMS.*

We regret to record the death of Professor A. S. Packard, the eminent zoologist of Brown University; of Mr. William Sellers of Philadelphia, the well-known engineer; of M. Paul Henry, the French astronomer, and of Professor Ernst Abbe, known for his improvements of optical instruments.

Scientific societies that met at Philadelphia during convocation week elected presidents as follows: The American Society of Naturalists, Professor William James, of Harvard University; the Geological Society of America, Professor Raphael Pumpelly, of Newport, R. I.; the Botanical Society of America, Professor R. A. Harper, of the University of Wisconsin; the Society of American Bacteriologists, Professor E. O. Jordan, of the University of Chicago; the American Anthropological Association, Professor F. W. Putnam, of Harvard University; the American Physiological Society, Professor W. H. Howell, of the Johns Hopkins University; the American Psychological Association, Professor Mary W. Calkins, of Wellesley College; the American Philosophical Association, Professor John Dewey, of Columbia University.

The city of Berlin has arranged a competition for plans for a monument to Rudolf Virchow. It is to be placed at the intersection of Karl and Luisen Streets, a square which will henceforth be known as Virchow Platz.—The famous singing master, Senhor Manuel Garcia, of London, who invented the laryngoscope fifty years ago, will be 100 years old March 17, 1905. The London Laryngological Society and other societies have arranged a celebration which includes the presentation of a portrait by Mr. John Sargent.—The Danish government has issued a stamp bearing the head of the late Professor Finsen with the object of placing within reach of the poorer classes a means of subscribing to the national monument by which it is proposed to commemorate his work.

Professor Ernest Rutherford, of McGill University, has been appointed Silliman lecturer at Yale University for 1905. The previous Silliman lecturers have been Professor J. J. Thomson, of Cambridge University, and Professor Charles S. Sherrington, of Liverpool University.—Dr. Livingston Farrand, professor of anthropology at Columbia University, has been placed in charge of the work of the National Association for the Study and Prevention of Tuberculosis.

President Eliot, of Harvard University, has been elected a corresponding member of the Academy of Moral and Political Sciences of the Institute of France.—Professor Lewis Boss, astronomer of the Dudley Observatory of Albany, N. Y., has been awarded the medal of the Royal Astronomical Society.—M. L. Troost, honorary professor of chemistry at the University of Paris, is this year president of the Academy of Sciences in succession to M. E. L. Mascart, professor of physics at the Collège de France.